

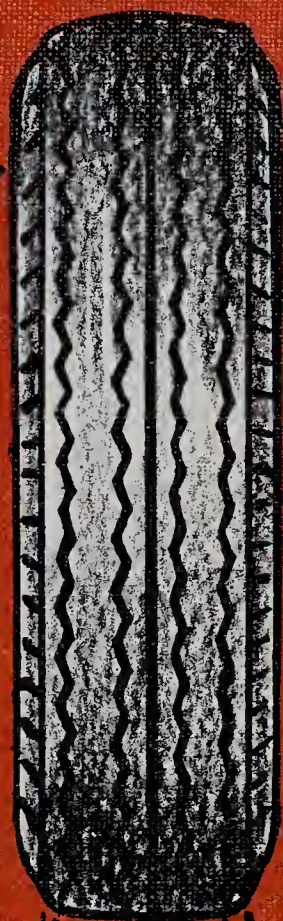
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The Magic of RUBBER

Written and Illustrated
by E. JOSEPH DREANY



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North America

Pacific Ocean

Hawaiian Islands

EQUATOR

THE WORLD'S RUBBER BELT

Costa Rica
Panama

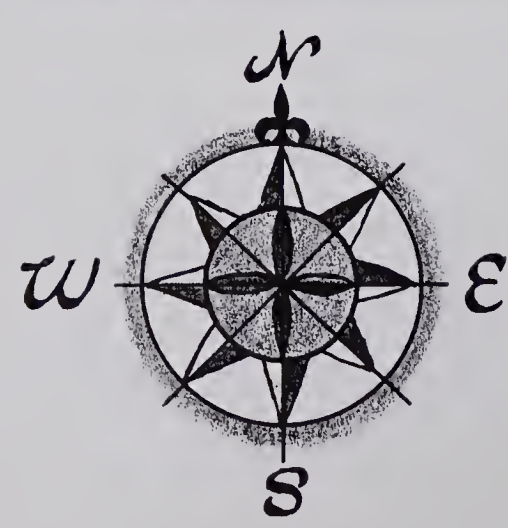
South America

Akron

New York

Haiti

New Zealand





Europe

Asia

Africa

Africa

India

Thailand

Ceylon

Philippine Islands

Belgian Congo

Sumatra

Indonesia

Indian Ocean

Australia

Distribution of
the World's Natural
Rubber Supply

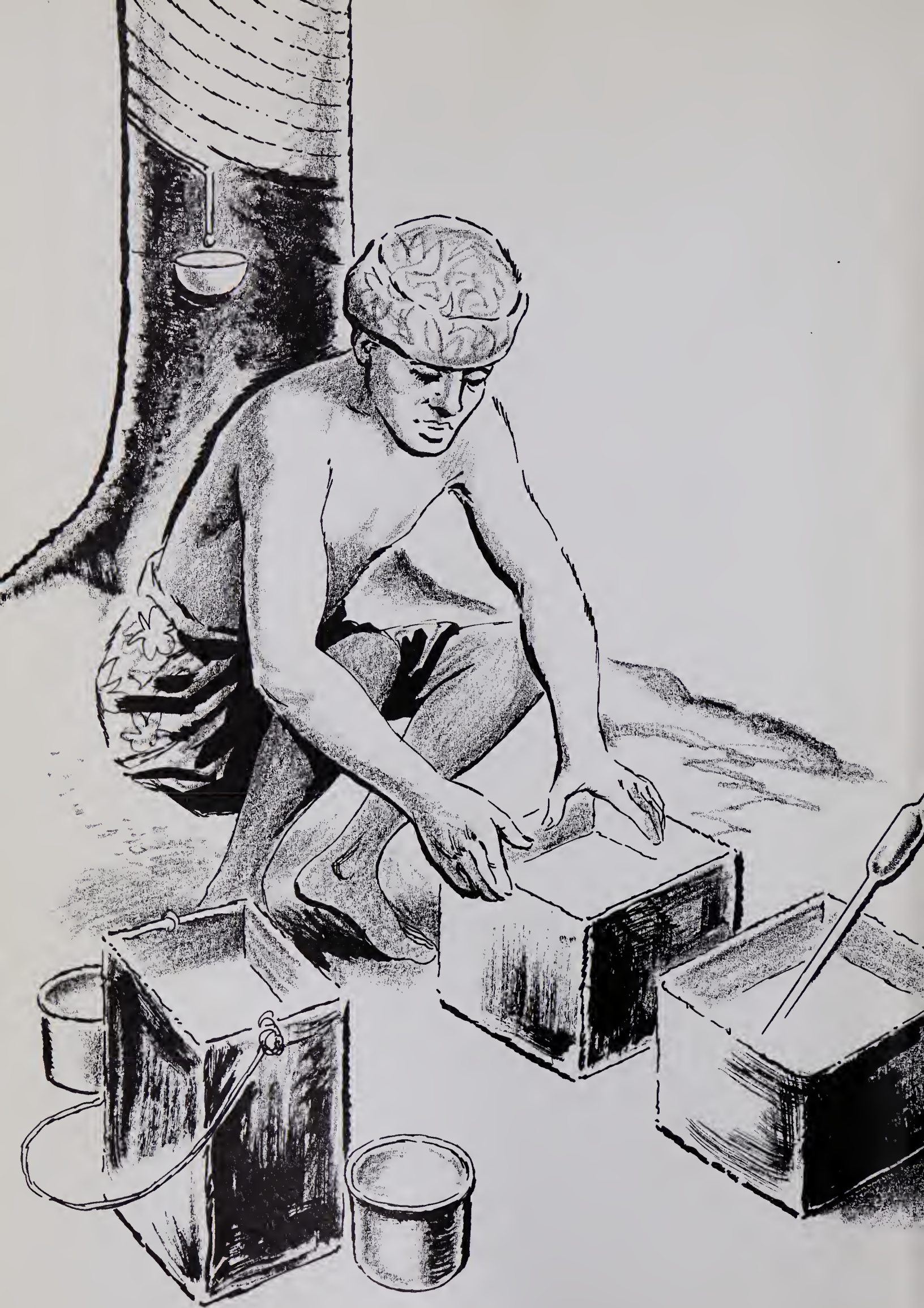




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Written and Illustrated by

E. Joseph Dreany

G. P. Putnam's Sons

New York



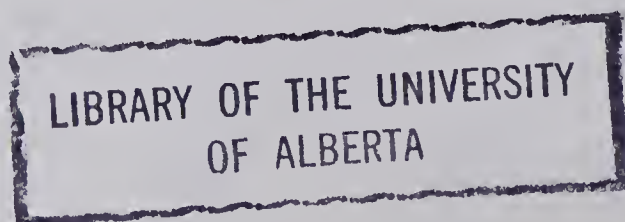
To Mel Crawford
A good sketching companion

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It is understood, of course, that the author alone is responsible for any error which may appear in this book.

THE MAGIC OF RUBBER



1. Erasers and Rockets

EVERYONE knows something about rubber. We use it every day. We know that it stretches, bounces, holds air, sheds water, and erases pencil and ink marks. Yet these are only a few of the things rubber can do for us. In fact, we use this amazing material in so many different ways that the life of almost every person on this planet has been changed.

A strong statement? Perhaps, but suppose all rubber suddenly disappeared on the day you were planning to take a trip to visit friends in France. You might just as well throw your ticket away. There would be no way for you to get to the airport, because no cars, taxis, or buses could get you there without tires. And even if you walked to the airport, the plane couldn't take off, since it has rubber tires, too, and hundreds of rubber

parts. You wouldn't be able to go by ship either, because its engines couldn't start without the many rubber seals and insulating wires which help them to operate.

So you have to stay at home. Life won't be very pleasant there. You can't let your friends know you aren't coming, for one thing, because all communication by telephone, radio and telegraph will be cut off. You won't have much of a lunch. The refrigerator has a rubber cord and rubber gasket, remember? And you can't heat a can of soup, because the electric stove won't work. You *can* have a sandwich — if you don't want it on toasted bread. Since the milkman couldn't make his deliveries that morning, you can't have milk with it. You have a warm bottle of pop instead.

Your father can't use his electric razor, your mother can't vacuum the living room and you can't listen to the phonograph or watch television. There is nothing left to do but go to bed. If your bed had a foam rubber mattress and pillow, it won't be a comfortable night, especially since the constant drip of water from faucets with no rubber washers will keep you awake.

And so it goes. When we think about rubber in terms of what life would be like without it, we can see what a priceless contribution it makes to our lives.

Rubber is everywhere and is one of the most versatile substances in the world. In a raincoat, water runs

off it, yet in a sponge, water is absorbed by it. The bowling ball that crashes into the pins at the end of the alley is rubber, yet so is the balloon that can be punctured with a pin. The eraser at the end of your pencil wears itself out in a few weeks, but it is made of the same material as tires, which are built to rub on thousands of miles of pavement without wearing thin. Rubber seals out heat in a refrigerator, yet it is a fine conductor of heat in a hot-water bottle or heating pad.

Rubber is friendly. It unites smoothly with many substances to form thousands of different combinations. And rubber can take a lot of bullying. It can be punched, pushed, pulled and pounded, and it will still bounce back and be ready for more. Rubber is quiet. There are no bangs, rattles, or squeaks when rubber is around. Without it, the world would sound like a giant machine shop.

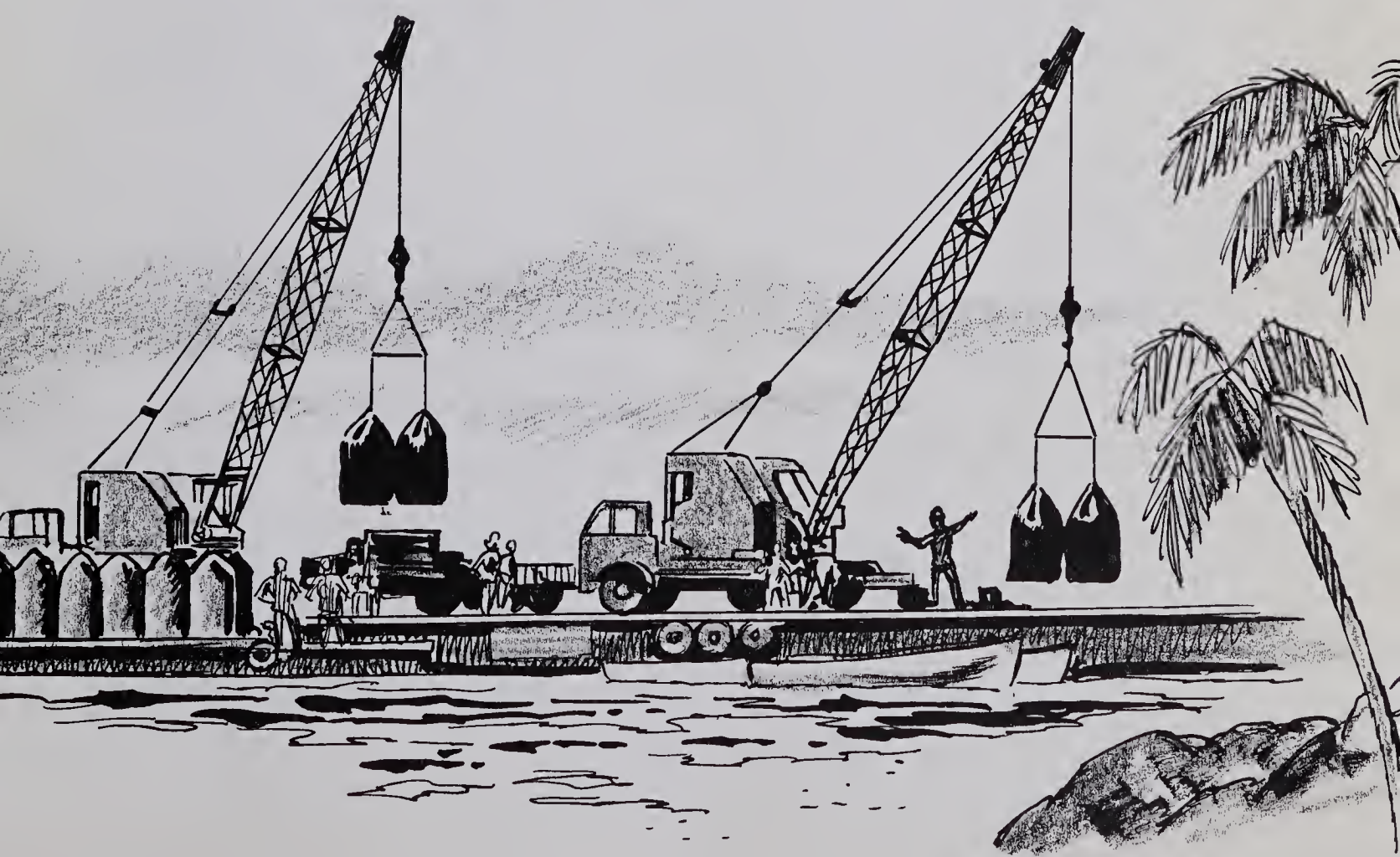
The modern world makes many demands on rubber, and it comes through with flying colors every time. For example, near the top of the world in the north of Greenland is Thule, an American Air Force base. The pilots, bomber crews and ground force live in temperatures which often reach 40 degrees below zero. In cold like this, an ordinary rubber ball becomes brittle and shatters like glass when it is struck with a bat. Yet this Air Force base depends on rubber for its very existence.

No matter how cold it is, these planes must fly each



day. Every part of the planes must always be in perfect working order, and every plane needs rubber before it can leave the ground. A special type of rubber has been created to meet these requirements. Fuel hoses are made from a rubber formula that keeps them flexible in the terrific cold. The men wear suits of a rubberized fabric that are much lighter and warmer than the old-fashioned fur and wool arctic clothing. Each rubber part of the planes must be made from a special recipe.

This is only one example of rubber's special uses. The experiments being made today to land human beings on the moon would be useless if it were not for rubber. Rockets would lose their precision if rubber



sheets did not protect them from wind and dust before they took off. Rubber protects and cradles the recording instruments inside the rocket. And when men travel into space in a rocket, they will probably be wearing suits of a special rubber composition.

It isn't necessary, of course, to go all the way to the moon to find activities in which rubber plays a vital role.

On a farm, rubber is used in tractors, loaders, combines, and milking machines. In a hospital, oxygen equipment, surgeon's gloves, "iron lungs," and even the tile floors are all made with rubber. In a few of the newest railroad terminals and sports stadiums, people get from place to place on fast-moving rubber belts. Similar belts carry ore in mines, carry fruit and vegetables in canning factories. Dentists use rubber for taking impressions and for making dental plates.

To return to the home, let's make a short list of some of the things we use every day which contain rubber:

electric wiring insulation	floor tile
refrigerator	electric plugs
telephone	rug underpadding
rubber door mat	rubber washers and gaskets
rubber gloves	washing machine
plastic dishes	chair tips
hot-water bottle	foam cushions

rubber sponge	garden hose
drainboard	television set
lamps	radiant heat panel
foam mattresses and pillows	vacuum cleaner

See if you can add to this list. It does not contain clothing items or toys.

What is this marvelous material which we find so useful? Where does it come from? Is it natural or man-made? Who discovered it and exploited its astounding qualities? This book will answer all these questions about the magic material called rubber, which we depend on every hour of every day. The biggest question of all is how we ever got along without it.



2. The Milkman of Sumatra

THERE are two kinds of rubber: natural and synthetic. Synthetic rubber first takes form amid the chemicals, test tubes and white-coated men of the modern laboratory, but the beginnings of natural rubber are quite different. Its story starts with a milkman in a carefully cultivated grove of trees on the island of Sumatra in the East Indies.

This milkman, like those in Milwaukee and New York City, starts his rounds early in the morning, but in most other ways he is not like the milkman of the city streets. The milkman of Sumatra rides to work on a bicycle. On his shoulder he balances a bamboo pole with a large tin can tied to one end and a rattan basket fastened to the other. The place where he gathers his "milk" is not a dairy but a plantation of trees with the botanical name *Hevea brasiliensis*, commonly called

“rubber trees.” The milk he collects from these trees is called “latex milk,” and in some ways it is like milk from cows. It is white and creamy and smells something like cows’ milk. It can be whipped into a rich lather. It will sour after short exposure to air. Tiny particles of rubber are suspended in the latex much as the globules of butter fat are suspended in fresh milk. As faithfully as a prize cow, the trees give forth latex daily in the cool morning hours through carefully made cuts in their bark.

Between the hours of 5 A.M. and 9 A.M., the time when the latex flows most freely, each milkman of Sumatra can tend about 350 rubber trees. His work is done shortly after the hot Sumatran sun rises and the trees begin to conserve liquid and halt their flow of latex.

The milkman’s first job is to remove from each tree the strips of rubber which have gathered and hardened from the previous day’s tapping. These strips go into the basket to be used in low-quality rubber.

Next, the milkman will use a hooked knife to shave off a thin strip of bark about halfway around the trunk. He is careful not to cut too deep into the tree and injure the cambium, or woody part, of the tree trunk. If he did this, fungus and rot would attack and kill the tree. He cuts only deep enough to release the latex, which flows between the inner bark and the cambium.

The cut slants down at an angle of about thirty degrees. At the lower end of the cut, he places a spout and under the spout a small cup like a teacup. The latex drips into this cup; after about an hour it will contain an ounce or so of rubber milk. The precious liquid is just like the white ooze from a milkweed or dandelion stalk, but only the rubber tree, of all the plants in the world, can produce enough latex to fill the great need for rubber.

As the milkman finishes his rounds at about nine o'clock, another worker on the plantation pounds a great hollow log with a stick. At this signal, the milkman goes back and empties all the little cups of milk into his collecting can. When the can is full, he goes to a collecting station. There the milk is weighed and strained through a sieve into a large tank, and the scraps of low-grade rubber are emptied from the basket. The milkman's day is over.

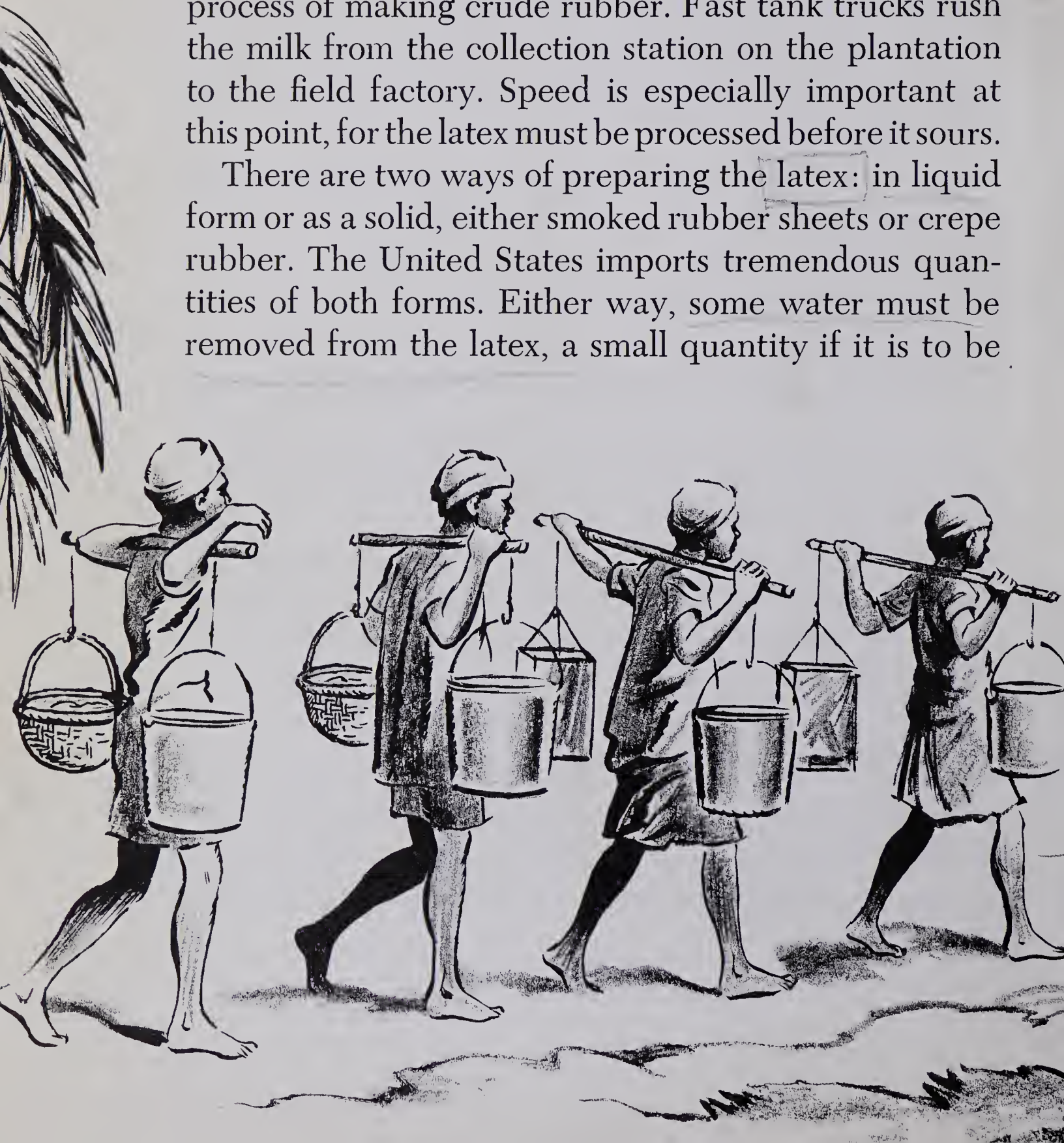
The milkmen of Sumatra usually work on large estate plantations with thousands of trees, but they may also work collecting latex from their own trees in a small plot of an acre or so. Latex gathered in this way is usually smoked over open fires to prevent its spoiling before it can be carried to market as crude rubber.

Of course, the milkmen of Sumatra are not the only workers gathering latex. Similar rounds are made daily by men on plantations in the Far East in Malaya, Indo-

nesia, Ceylon, Thailand, India, as well as in Africa in the Belgian Congo, Liberia and Nigeria. All of these places contribute to the modern world's great demand for natural rubber.

Collecting the liquid latex is only the first step in the process of making crude rubber. Fast tank trucks rush the milk from the collection station on the plantation to the field factory. Speed is especially important at this point, for the latex must be processed before it sours.

There are two ways of preparing the latex: in liquid form or as a solid, either smoked rubber sheets or crepe rubber. The United States imports tremendous quantities of both forms. Either way, some water must be removed from the latex, a small quantity if it is to be



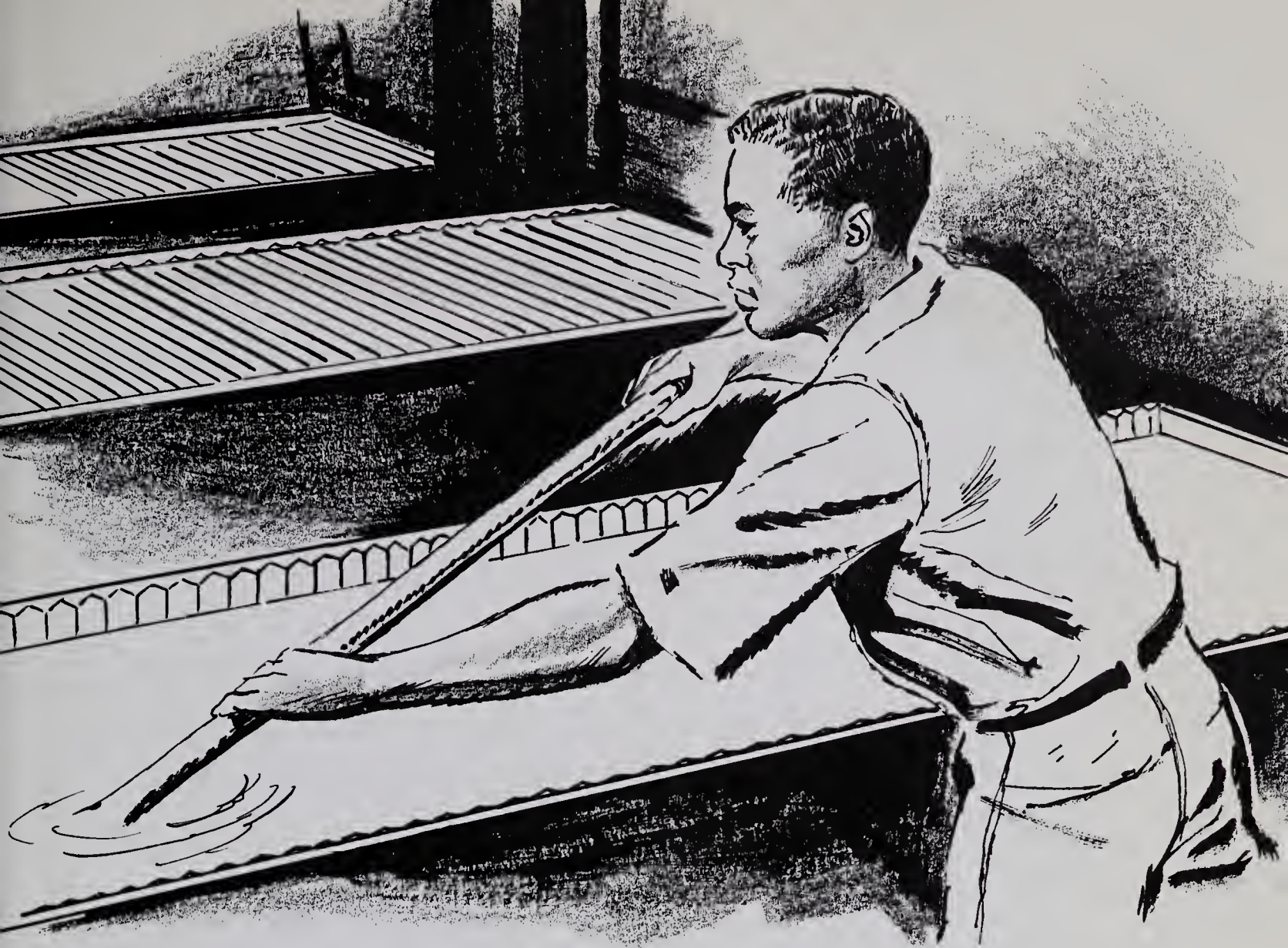


shipped as a liquid, and much more if solid rubber is wanted.

If you have ever seen a cream separator in operation on a farm, you already have some idea of how the latex is separated from the water. The machine used for the process is called a “centrifuge” and the method, as you may already have guessed, is the centrifugal method. The liquid latex is poured into a cylindrical machine which revolves at the tremendous speed of 6,720 revolutions a minute. The rubber is lighter than the water with which it is mixed, and it is therefore forced out to the edge of the cylinder while the heavier water stays in the middle. The rubber is channeled to the top of the machine and can be skimmed off as it accumulates. In just the same way cream, which is lighter than milk, whirls to the edges and top of the cream separator, leaving the heavier skim milk in the middle.

Ammonia is then added to the liquid latex to keep it from solidifying any further and the mixture is stored in huge tanks until it is needed for export. It is the liquid form of rubber which is used to make rubber gloves, foam rubber mattresses, adhesive tape, rubber toys, and many other products.

If the latex is to be exported in dried form, another method of removing the water is used. The latex is poured into dilution tanks and mixed with an equal quantity of water. This mixture flows into shallow



tanks beneath, which have slots evenly spaced at the sides. As the water ^{goes off} evaporates, partitions are fitted into these slots to shape the hardening latex into slabs. When the tanks are full of the latex-water mixture, acetic or formic acid is added.

Overnight, the latex hardens into spongy, water-soaked curds called "coagulum." In texture, this looks something like the bean curds you may have eaten in a Chinese restaurant. It takes three pounds of latex, more or less, to produce one pound of the coagulum. The next step is to remove the coagulum from the tanks and squeeze it between metal cylinders into long

sheets. These sheets are cut into convenient lengths and hung on tall racks like clothes hung out to dry. The racks are wheeled into the smokehouse and, like bacon and ham, the rubber is smoked for about fourteen days. The smoking dries and cures the rubber so that it will not be spoiled by fermentation. During the smoking treatment, the rubber changes color from its natural white to deep amber.

Crepe rubber is not smoked, but merely hung up in thin sheets on poles, and allowed to dry and cure in the open air. Because the crepe is not smoked, it does not turn amber. Its natural color is that of the artgum erasers which artists use.

Now the processing of the rubber is complete. The solid rubber is tied into huge bales and carried by locomotives, launches, barges, and bullock carts to the sea-ports, while the liquid latex is brought by the same tank trucks which took it to the factory. The freighters are waiting for it, to carry it to the United States and other countries, where it will be manufactured into all the many rubber products we have already talked about.

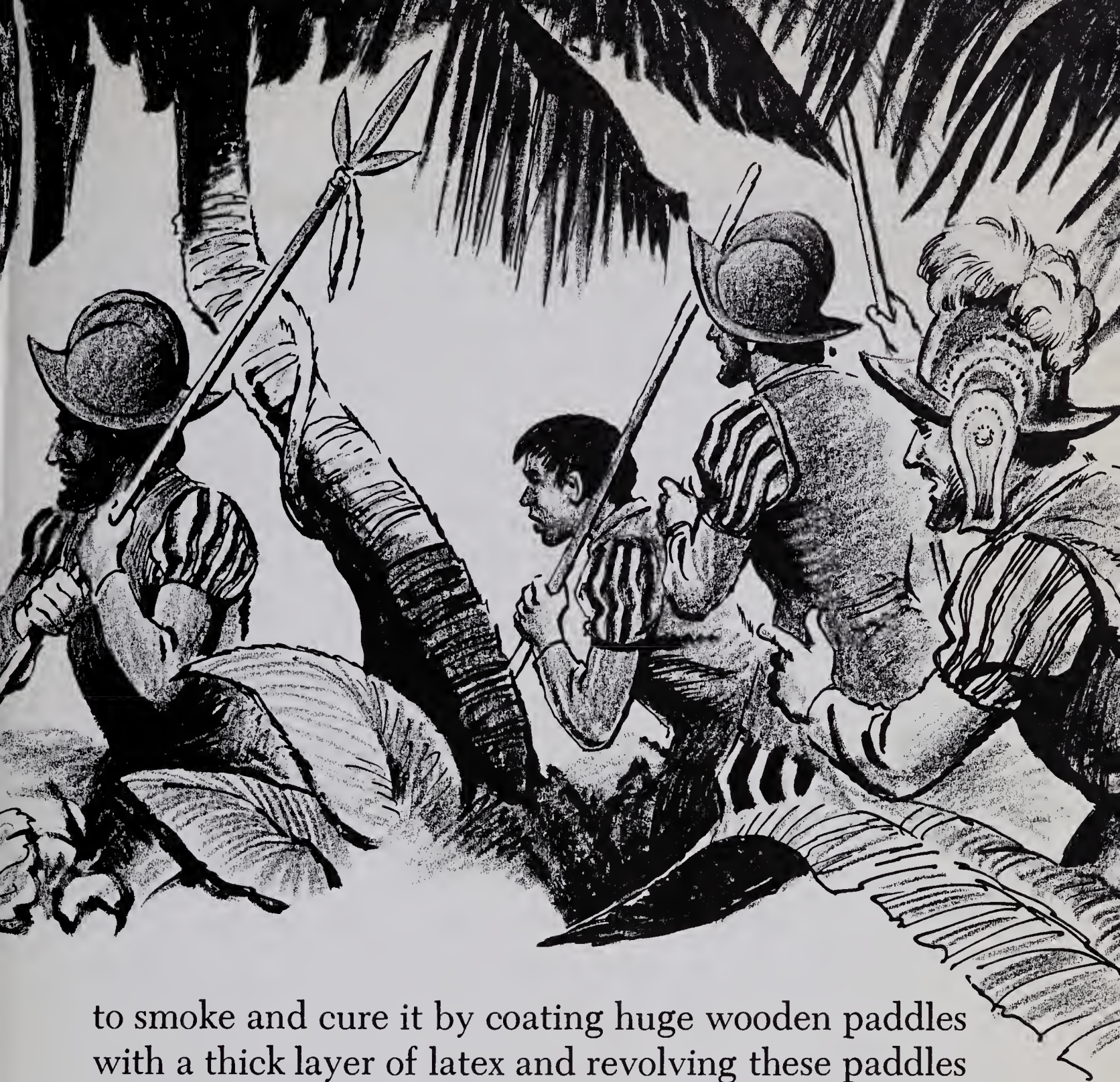
3. Rubber's Past

RUBBER got its name around ~~1770~~ when Dr. ~~Joseph~~ Priestley, (better known for the discovery of oxygen,) found that he could rub out pencil marks with this strange stuff that had begun to arrive in Europe. It was scarce and expensive, though. You could buy a half-inch cube of it in a few London shops, but that tiny piece (cost three shillings,) or about seventy-five cents. For this reason, most people went right on erasing their mistakes with the bread crumbs which had always been used for this purpose, and nobody paid much attention to rubber. *Show mass*

Outside of Europe, rubber has had a very long history. Early picture writings of the Egyptians and Ethiopians, hundreds of years before the birth of Christ, show men and boys playing games with rubber balls. In India and China, there is evidence that rubber has been known for many thousands of years.



when One of the first written accounts of rubber *happened* is Antonio de Herrera's, the Spanish historian who recorded Columbus' second trip in 1493. He tells how Columbus saw the Haitian natives playing with balls of a gummy material. This gummy material was rubber. And long before Columbus' voyage, the Amazon Indians had rubber balls, rubber water jars and syringes, and rubber sheaths for their poison darts. The Amazons, indeed, were the first rubber chemists. They learned how



to smoke and cure it by coating huge wooden paddles with a thick layer of latex and revolving these paddles over smoky, green-wood fires.

They used the latex to coat their bodies with ceremonial and war feathers. Their medicine men discovered that cuts and bruises on the feet could be prevented with a thick coating of latex. These rubber "shoes" are the great-grandfathers of our sneakers.

The Indians found other uses for rubber. Their

drummers produced a mellow tone by coating the head of their clubs, or drumsticks, with rubber. And we mustn't think that Halloween masks are a recent invention, for these same Indians had fierce war masks of rubber, with the features of animals or angry imaginary gods.

The modern game of basketball is a distant relative of the Mayan game called Tlachtli, which Cortez and other Spanish explorers saw and described. The game was played on a stone court. On each side of the court were stone rings extending from the wall like basketball hoops. The Mayans, divided into two teams, knocked the ball through the hoops with any part of their bodies except their hands, and bets were made on the outcome.

It may have been Charles de la Condamine, the French scientist, who first introduced rubber to Europe. When he was in South America in 1736, he saw trees which oozed white drops, and called them "the trees that weep." He brought back samples of the material to France, but was unsuccessful in his attempts to turn it into waterproof cloth and a case for his quadrant. Nobody had yet learned how to make this strange substance behave.

By 1820, "India rubber" shoes were on sale in the United States, but they were very unreliable. In hot weather the shoes stuck to the pavement, and in the

winter the shoes would become brittle and crack. It was obvious that many experiments with rubber would have to be made before it became a stable product. It would never be commercially profitable until — and unless — this could be done.

Charles Macintosh, a Scotsman, was one of the first to try to stabilize rubber's properties. In 1823, he dissolved some rubber in naphtha and produced a solution that looked like honey. He pressed two pieces of cloth together with the rubber solution between them, very much like a huge rubber sandwich. And so the first raincoat was born, and the word "mackintosh" was added to our language.

At about the same time, an Englishman named Thomas Hancock sensed the profit which could be made from rubber products and opened a small rubber factory. Disturbed at the many scraps of rubber which were being wasted when the finished articles were trimmed, he invented a machine which he called a "pickle," which would reprocess the bits and pieces of rubber into a solid mass. A spiked rod inside a hollow cylinder was revolved by a hand crank, stirring and mixing the rubber until it solidified. This was the first rubber mixer and the most modern machines, called "masticators," still use the same principle.

*made
1st rubber
mixer*

Now the rubber boom really began to grow. E. M. Chaffee founded the Roxbury India Rubber Company

A company



Indians playing Tlachtli



near Boston and made life preservers, caps, boots and shoes, all of rubber-coated cloth. His contribution to rubber refining was the addition of small amounts of turpentine and lampblack to the raw latex, which gave the finished products a glossy finish. These sold so well that other American companies sprang up.]

But the same thing always went wrong. As soon as the temperature rose, the hot sun turned all of these rubber goods into nasty-smelling, molten masses. They had to be buried, they smelled so bad. Anyone who has ever smelled rubber burning will know exactly what the problem was. Overnight the “India rubber fever” collapsed. Things looked very black for the rubber business. If some way could not be found, once and for all, to keep rubber pliable and stable in both heat and cold, the industry would die.

4. Mr. Goodyear's Rolling Pin

*But a man called Mr. Goodyear
thought he could solve the
problem*

IN 1843, when the rubber industry desperately needed a savior, a persistent Connecticut Yankee named Charles Goodyear entered a shop to buy a rubber life preserver. Although nobody knew it then, the solution to rubber's instability was almost within sight. It seemed as if fate had guided Goodyear's steps. A chance conversation with the agent of Mr. Chaffee's Roxbury company revealed the seemingly hopeless plight of the industry. Goodyear was fascinated by the problem. He thought he could solve it. He immediately resigned from his hardware business and devoted the rest of his life to rubber.

Goodyear was not even a chemist, but what he lacked in training he made up for in fervor and single-mindedness. He plunged into the mysteries of organic chemistry with the same passion that other men feel

*I
where
have
heard
this
before
over*



for fever-ridden jungles and distant mountain peaks. He thought that the problem of curing rubber would take no time at all to solve.

Setting up a workshop in the kitchen, Goodyear started his experiments by making thin films of rubber with his wife's rolling pin. He determined to mix crude rubber with every known substance on the face of the earth until he arrived at the right answer. Into the rubber went everything in the kitchen. In time he tried salt, pepper, sugar, soap, castor oil, mustard, sand, and even homemade soup.

With some ^{money} capital he opened a shop and began to sell rubber shoes. But it was the same old story. The shoes turned into evil-smelling messes, and the customers wanted their money back.

He went out of the shoe business and back to his

experiments. Ink, cream cheese and witch hazel were some of the things that went into his strange mixtures. What peculiar conglomerations they must have been. Crude rubber, at best, does not smell like roses. When these odd ingredients were added, some smells unique in history must have come out of the inventor's kitchen.

Time after time, Goodyear went bankrupt and called on his friends to help him. He was thrown into jail for debt. He borrowed money for experiments but would not spend any of it for food. He pawned everything he could. His wife's last silk petticoat was used to make rubber hats. He grew weak and ill from hunger, and his family was forced to live on roots and potatoes.

The old Roxbury company, still in business, offered him other chances to experiment. His efforts with shoes and cloth finally showed improvement. The United States Government gave the firm an order for one hundred and fifty rubber mailbags. Success now seemed assured, but two weeks of hot weather reduced the mailbags to a sticky mess. Once more Goodyear was bankrupt and his family was short of food.

A less dedicated man would have given up at this point, beaten and discouraged. But Goodyear was stubborn and persistent. He felt that rubber could be made useful to mankind, and he was determined to be the man who accomplished it.



One winter Goodyear was doing research in his brother-in-law's kitchen in Woburn, Massachusetts. He accidentally dropped some rubber mixed with sulphur on a hot stove. Most of it charred like leather, but Goodyear was surprised to see a tiny portion that seemed perfectly cured. He nailed a piece of the rubber outside the kitchen door in the cold, frosty air. Next morning, he found it as flexible as ever.





Goodyear realized he had solved the riddle of rubber. It was the combination of gum elastic, sulphur, and heat. The method Goodyear discovered is now called “vulcanizing,” after Vulcan, the Roman god of fire. In fairness to Thomas Hancock who, you will remember, invented the “pickle,” it should be added that he had arrived at almost the same answer, working independently in England.

And so the problem was solved. Goodyear’s discovery paved the way for tires that would hold air without losing their shape, and rubber articles that would not decompose in normal heat or cold. He brought rubber from the state of an unstable novelty to that of a useful



and highly profitable substance. Unfortunately, Goodyear did not reap the rich financial rewards from his discovery. Plagued by lawsuits, he was deeply in debt at his death.

Although Goodyear's fate was not a happy one, the rubber industry entered a boom period that has never diminished. The demand for rubber skyrocketed. Prices soared. At the end of the Civil War, a stampede to the tropics began, and the price of rubber rose to \$1.07 a pound.

Fortune seekers poled and paddled their way up every branch of the Amazon River. The Indians left

The new
spread
around
the world

picture

their villages to gather the valuable white drops. Fields were left idle, and agriculture abandoned. Foodstuffs were imported into regions that once were self-supporting. Along rivers that teemed with fish, canned sardines and salmon were eaten. Time was too precious to stop and gather food. The wealth of rubber, not gold, was the magic lure. Adventurers and riffraff of all nations joined the mad dash into the malaria-ridden jungles of Brazil.

As rubber prices soared, fortunes were made and lost. Primitive villages like Pará and Manáos became cities with boulevards and opera houses. Great mansions with imported tile roofs were built far upriver by the rubber "kings." Pianos and costly furniture were transported by steamboats to these palaces in the jungle. Everyone was getting rich, except the native gatherers. Even a peddler of panama hats made a fortune.

In 1876, Henry Wickham, an Englishman, changed the location of rubber's destiny from West to East. He gathered about 70,000 seeds of the hevea tree in Brazil and packed them carefully between dried wild banana leaves. They were shipped to England, along with many hundreds of young hevea trees. In London precious orchids were moved from the Royal Botanic Gardens at Kew to make room for the even more precious rubber seeds and plants.

Seedlings were shipped to Ceylon, and the first of

Small
trees

*- place rubber
under no grown
Picture.*

the vast Eastern plantations was born. Others were taken to Indonesia and India. Many were set out on dying coffee plantations. As the East turned from coffee to rubber, Brazil began growing coffee to make up for the lost rubber market. The Brazilian crude wild rubber could not compete with the superior product of the carefully tended Eastern plantations.

In 1934 a strange cargo arrived in Brazil. Aboard the ship were 5,000 budding trees from Malaya, Java, and Sumatra which began a new life on a rubber estate on the very Tapajoz River where Henry Wickham had gathered his seeds over half a century before. These descendants of the original precious cargo had come home again.

Rubber trees of pedigreed stock have been planted in Panama, the Philippines, and Costa Rica. There are also rubber estates in Liberia and other parts of Africa; but most of the world's natural rubber still comes from the Far East.

Perhaps none of this fantastic growth would ever have come about if Goodyear had left sulphur off his list of things to combine with rubber. }



5. A World on Wheels

RUBBER processors and manufacturers had had plenty of time to iron out all the kinks in rubber vulcanization by the turn of the century. At just about this time, the automobile business was born, and with the automotive age, the rubber industry moved into its highest gear. Tires of all kinds, for every variety of wheeled appliances, are now the biggest single item of rubber manufacture. Automobile tires and tubes alone use twice as much rubber in their manufacture as all other rubber products combined. It is as if Macintosh, Hancock, Goodyear, and all the unsung rubber pioneers were making sure that when we had automobiles, we would have the proper kind of rubber for them to roll on.

“Get a horse!” “Lookit the horseless buggy with the motor — it’ll never work!”

Jeers like these greeted the appearance of the first

motorcar. The grocer put down the cheese he was slicing and ran to the big window of the country store. The livery stable man hurried to join the group of idlers and whittlers on the front porch. Farmers leaped to hold the heads of their terrified horses as the wheezing, bucking monster roared by in a cloud of dust and fumes.

It was a daring man indeed who sat behind the controls of this newfangled contraption. He not only had a hostile public to contend with, but also roads that were narrow trails, and city streets that were crudely paved. There were no gas stations. Each motorist had to be his own mechanic. Extra gas, ropes, and all kinds of tools were carried on a long trip. In wet weather the roads turned into puddles of mud. In dry weather the dust was so thick that the pioneer auto fan wore goggles, and a long white linen coat called a "duster."

Life was rough in the early days of motoring. Imagine what it would have been like without rubber tires to absorb most of the shock. Did the automobile make the rubber industry or was it the other way around? It is hard to think of one without the other, but between them they just about ruined the buggy whip business. It seems a far cry from the sleek shiny cars of today to those old gas buggies that shattered the peaceful countryside with noise and smoke. But it was only yesterday.

In 1893, the Duryea brothers had made the first successful gasoline-powered car. It tore down the streets of Springfield, Massachusetts, at the reckless speed of about five miles an hour. In 1896, Henry Ford steered his first car out of his little Detroit machine shop, and the rest is history.

In 1900, there were only about 8,000 automobiles registered in the United States, but by 1902 the number had leaped to 23,000. Groups of motor fans formed touring clubs. Trips into the surrounding countryside became very popular.

When the first “horseless carriages” appeared on the roads, the motor age began and with it the rubber age. While the growth of the electric industry, with its many uses of rubber in insulation, also called for a great increase in rubber production, it is still automobile tires we think of first when rubber is mentioned. Nowhere is the use of rubber more impressive than in the huge tire manufacturing plants. One of the biggest of them has a huge, revolving platform called a “merry-go-round.” All of the machines about to be described that are necessary to make a tire are fastened to the platform. Crude rubber goes into the first of these machines, passes automatically to the second, the third, etc., and comes out of the last machine as a finished tire. All that the men in this plant have to do is to keep their eyes on the machines to make sure they are all



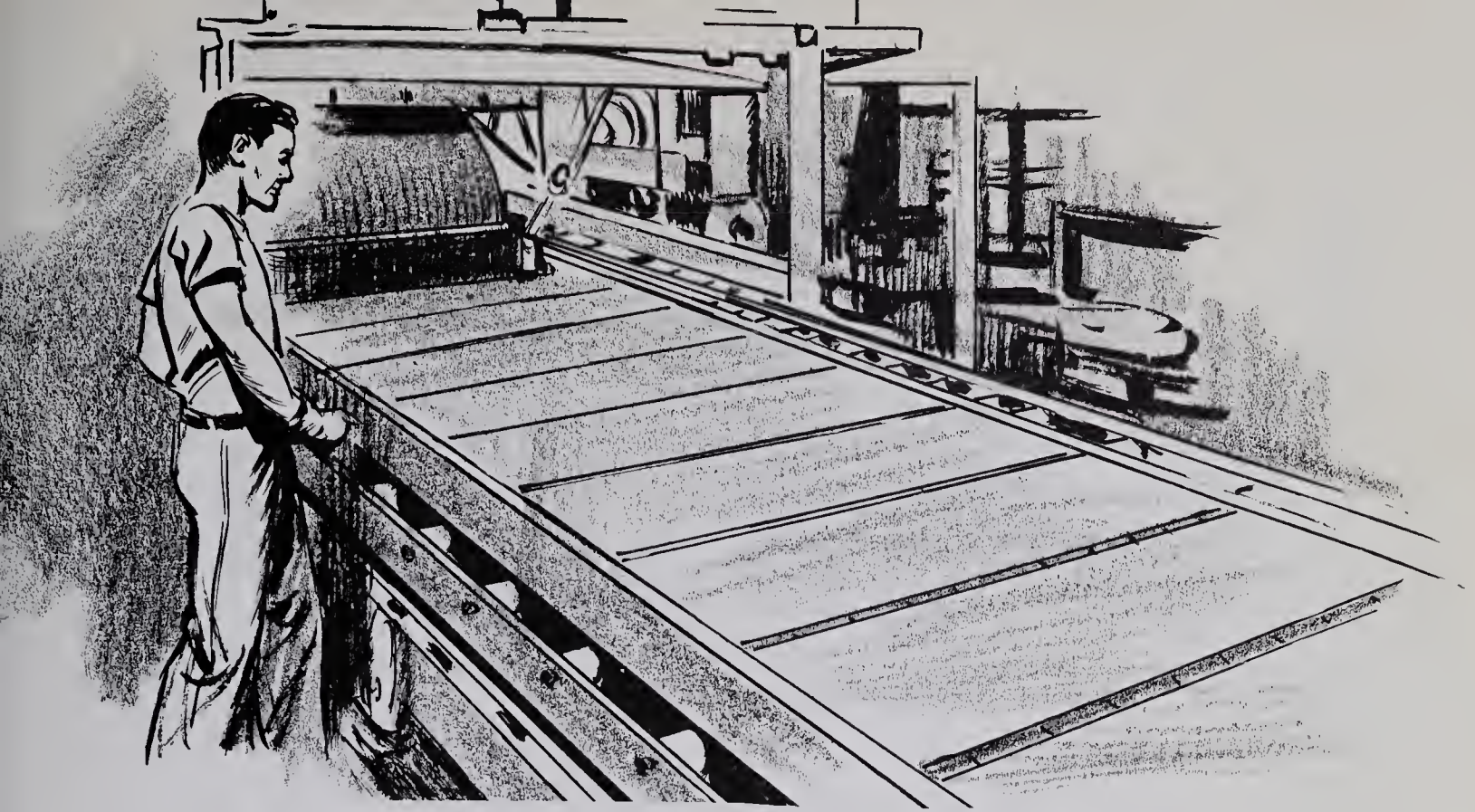


functioning properly. "Automation" is the term used to describe such a fully automatic process.

In many other factories, bales of crude rubber like those we last saw on the dock at Sumatra are first thrown into a machine called a "pie cutter." Electrically heated blades slice the "rubber pie" into pieces, and then these pieces are chewed until tacky between rough water-cooled rollers. This rubber pie may not be very tasty, but thousands of pounds are gobbled up every day by the hungry automobile business. From this cutter the rubber comes out in slabs, and is hung up to dry.

The mixing mill is the magic machine in which crude rubber loses its identity. From a stock of over 500 chemicals, chemists prepare the correct formula for each batch of rubber. The kind of mixture depends upon the way the rubber will be used. These special mixtures are poured between the walls of rotating cylinders and combine with the crude rubber. According to the directions for tires, carbon black, zinc oxide, petroleum products and vulcanizing agents are added to the crude rubber.

Great Banbury mixers in some factories do the same work on a larger scale. On the third floor of one of these buildings a man adds the ingredients to the machine. They drop through to the Banbury mixer on the second floor. After mixing, the rubber compound drops down



again to the slab-off mill on the ground floor and goes by conveyor to storage.

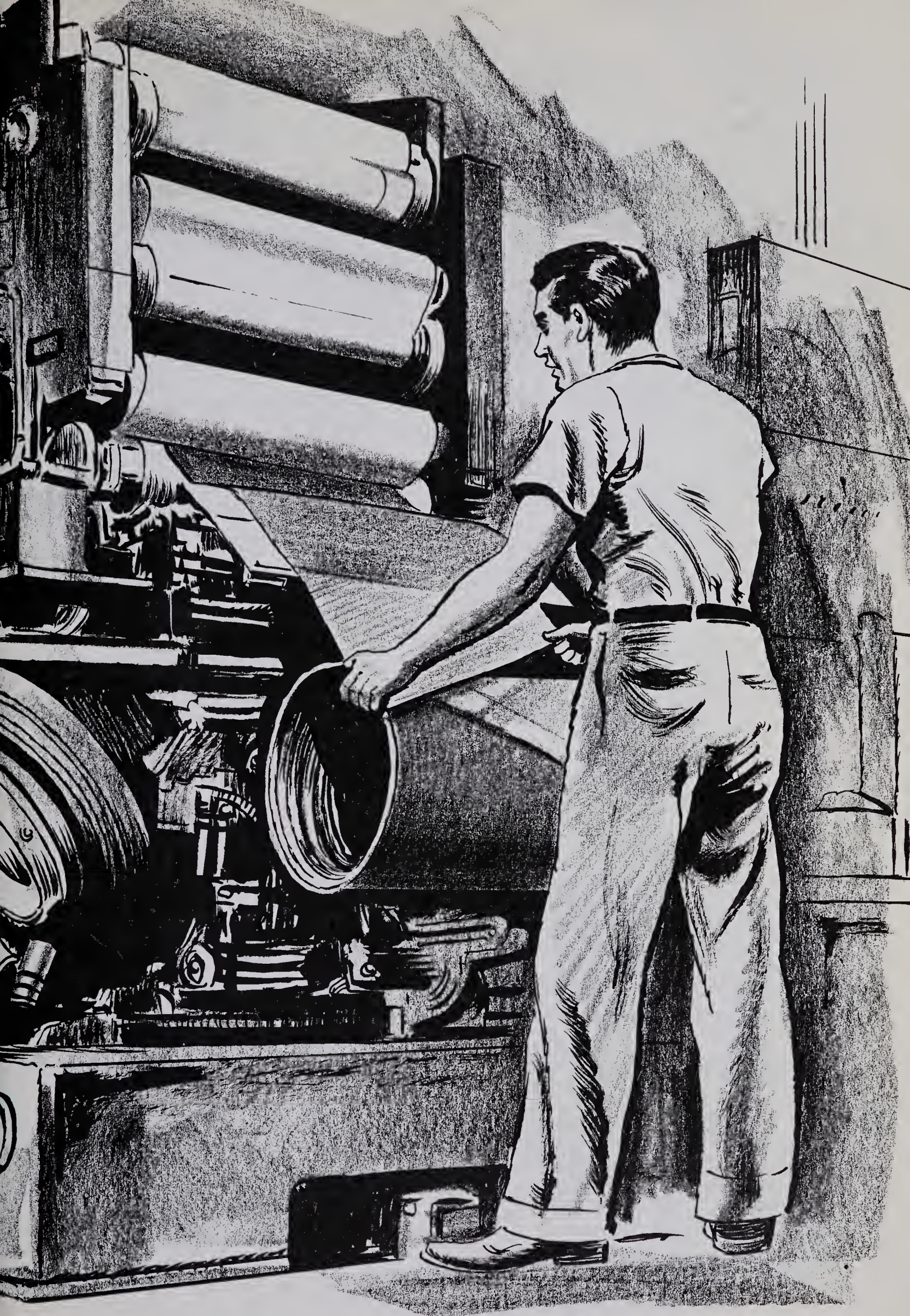
From the storage area, the rubber slabs are again brought out and go through a “warming-up” mill. A baseball pitcher always warms up in the bull pen before stepping out on the mound to face the first batter. Like a baseball pitcher, rubber must be warmed up to give its best performance. Through various machines the rubber is taken off in strips, goes through dies, and comes out in the shapes needed for the various treads of tires. Meanwhile, the tire-cord fabric, which is the main part of the body of the tire, is also being made. Tire cord of rayon or nylon is dipped in liquid latex. In a massive machine called a “calender,” rubber is squeezed in between the cords to form a rubberized fabric. Steam or water is forced inside the squeezing rollers to regulate the temperature.

The third most important part of the tire is the “bead,” which holds the tire securely on the wheel. The bead is prepared from three to ten strands of the strongest type of bronze-coated steel wire. Each strand is completely coated with rubber, made into a loop, and wrapped in rubber-coated fabric. A triangular strip of rubber is molded on top of the bead. This helps to fuse the bead into the cured tire. Finally, another strip of rubber-coated fabric is applied to anchor the bead to the tire body.

A great deal of work has been done, but much more is to come before the parts of the tire are joined into their familiar shape. On the main floor of the factory, many workers are using the prepared materials to build the finished tires.

One man stands before a tall machine in front of a small revolving steel drum. This drum turns whenever the operator presses a pedal. From between big rollers he pulls down a sheet of rubberized fabric. The rollers look like the wringer on an old-fashioned washing machine, similar to the one your grandmother may have had.

The fabric is quickly and neatly pressed around the drum and the piece is cut off at an angle. A second ply of fabric is spliced around the drum. The cords in this fabric run in the opposite direction to the first piece. This gives the tire greater strength. The two

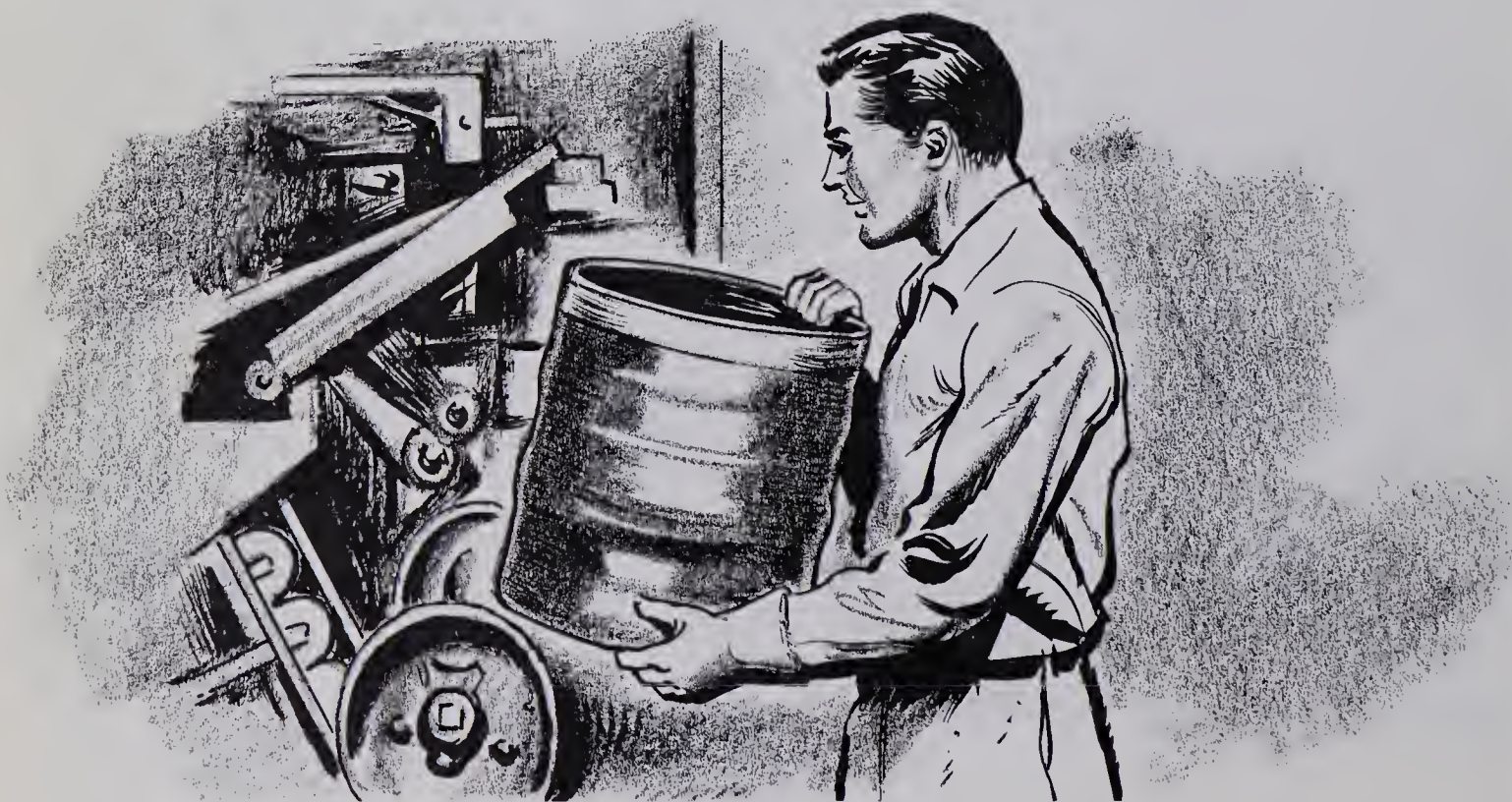


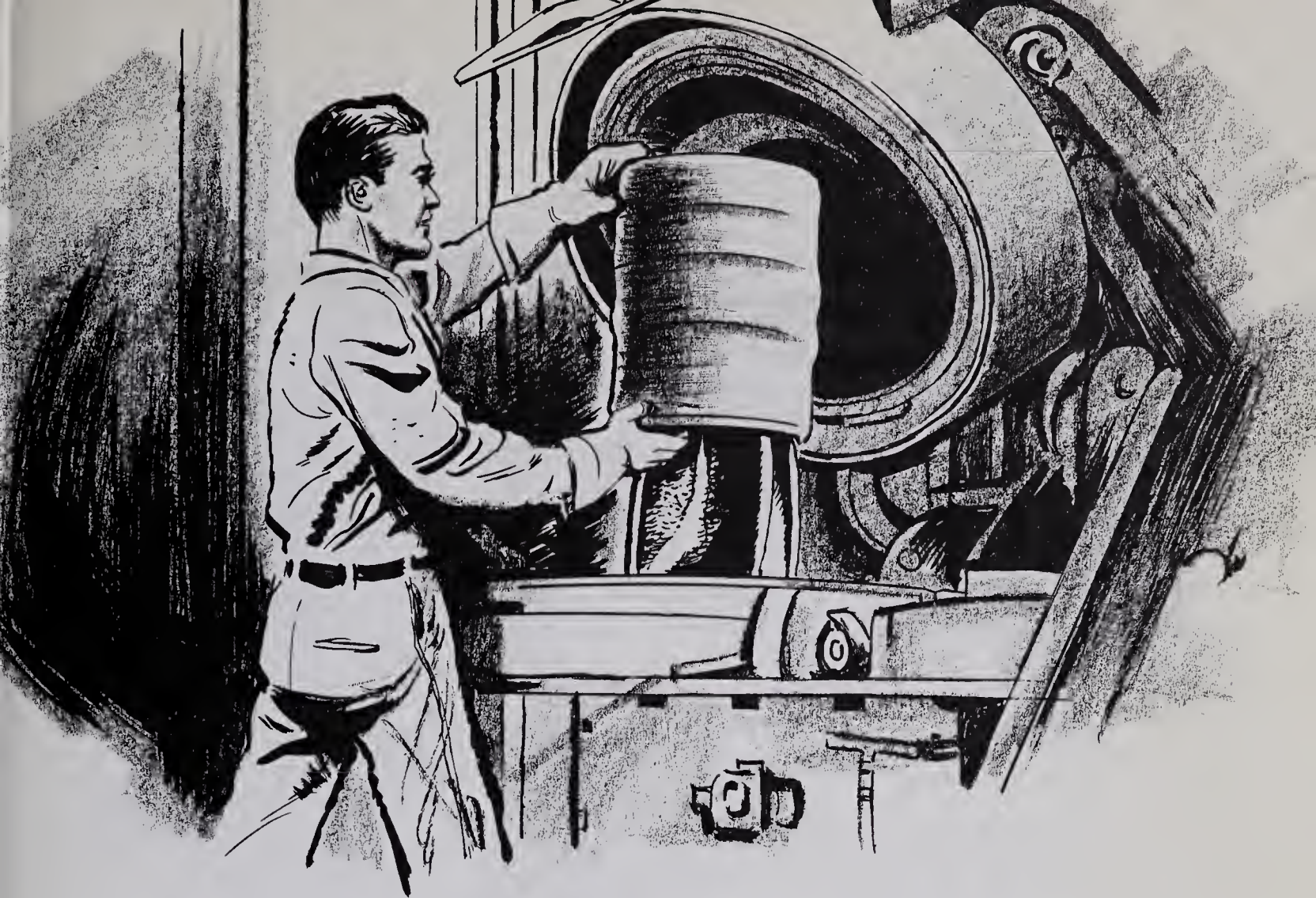
plies are forced together by an automatic roller called a “stitcher.”

After pressing the ends of the first two plies down around the drum, the bead is set into position. The ends of the two plies are then turned up around the bead, locking it firmly into position. The tire maker adds two more plies and an additional layer of fabric called a “shock ply.” Most automobile tires are made in four or six ply. The bead is further reinforced by a length of rubber.

With the main part of the tire finished, the operator adds a thin strip of white rubber. “This will be the white side wall in the completed tire,” he explains, as he quickly revolves the barrel.

A deep layer of rubber forming the tread is now put on the drum and pressure-rolled. The ends of the third and fourth plies are turned down around the edge of the tire. Now the drum is collapsed and the tire removed. At this point, it looks something like a small

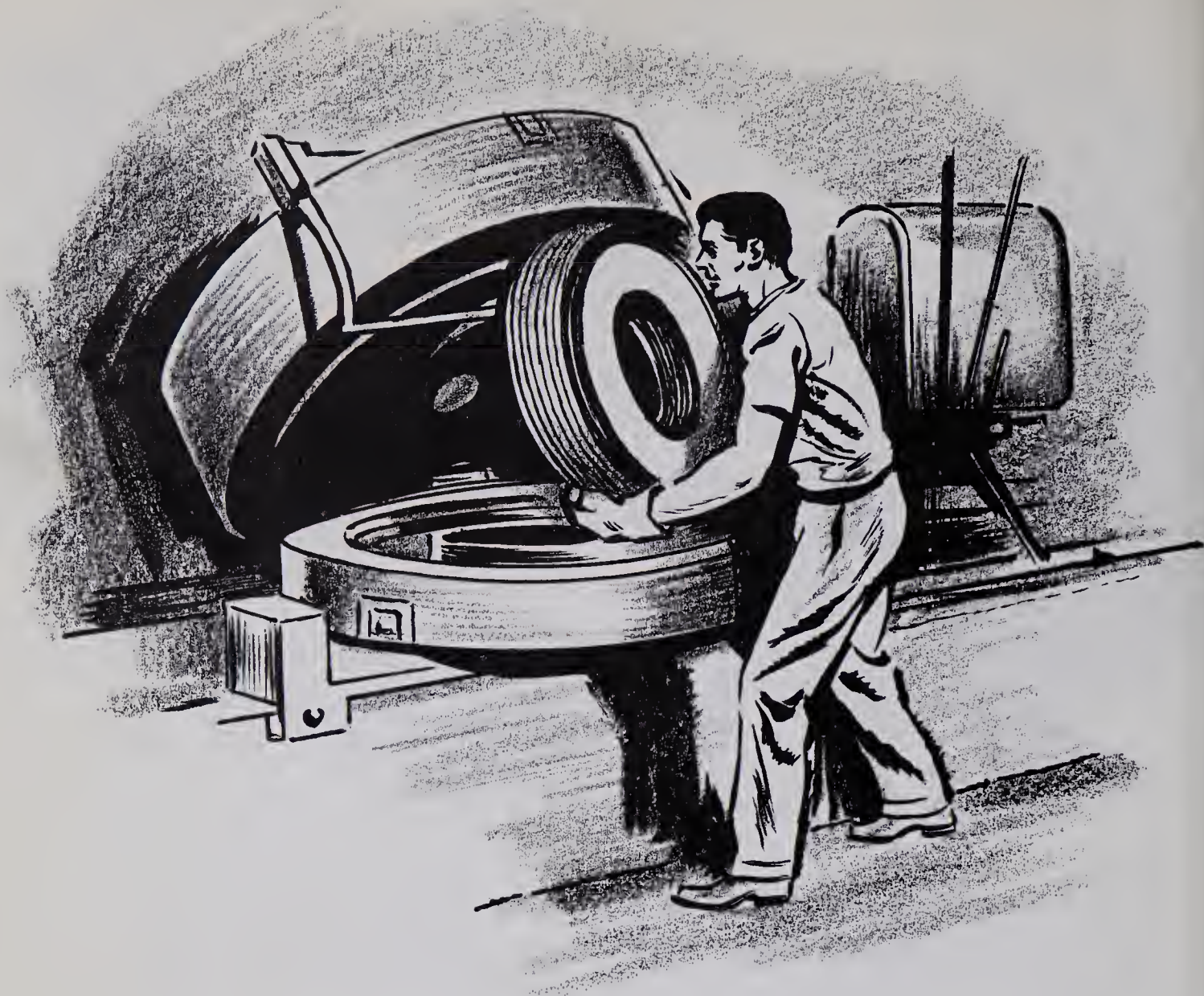




black barrel without ends. The tire barrel is placed on an overhead conveyer which carries it to the inspection department.

The whole operation takes only a few minutes. After inspection for flaws, the barrels move along to the kitchen where master chefs bake these little hollow drums into bigger black doughnuts.

The baking and curing of the drums is done in an efficient and fully automatic machine called a Bag-O-Matic or an Autoform. It is a steam-heated mold with hinged halves which form the outer shape of the tire with its familiar tread marks. The drum is put into the mold, which closes firmly around it, and intense steam heat forces the drum into the shape of the mold. At the



same time that this process is taking place, a rubber bag inside the mold is inflated with steam to press against the inside of the tire, and this steam pressure forces the tread and side wall of the tire into the design cut in the metal mold. The entire process takes about thirty minutes at a temperature of around 300 to 320 degrees Fahrenheit. When the two halves of the machine are opened, the barrel-shaped object that went into it emerges as a finished tire.

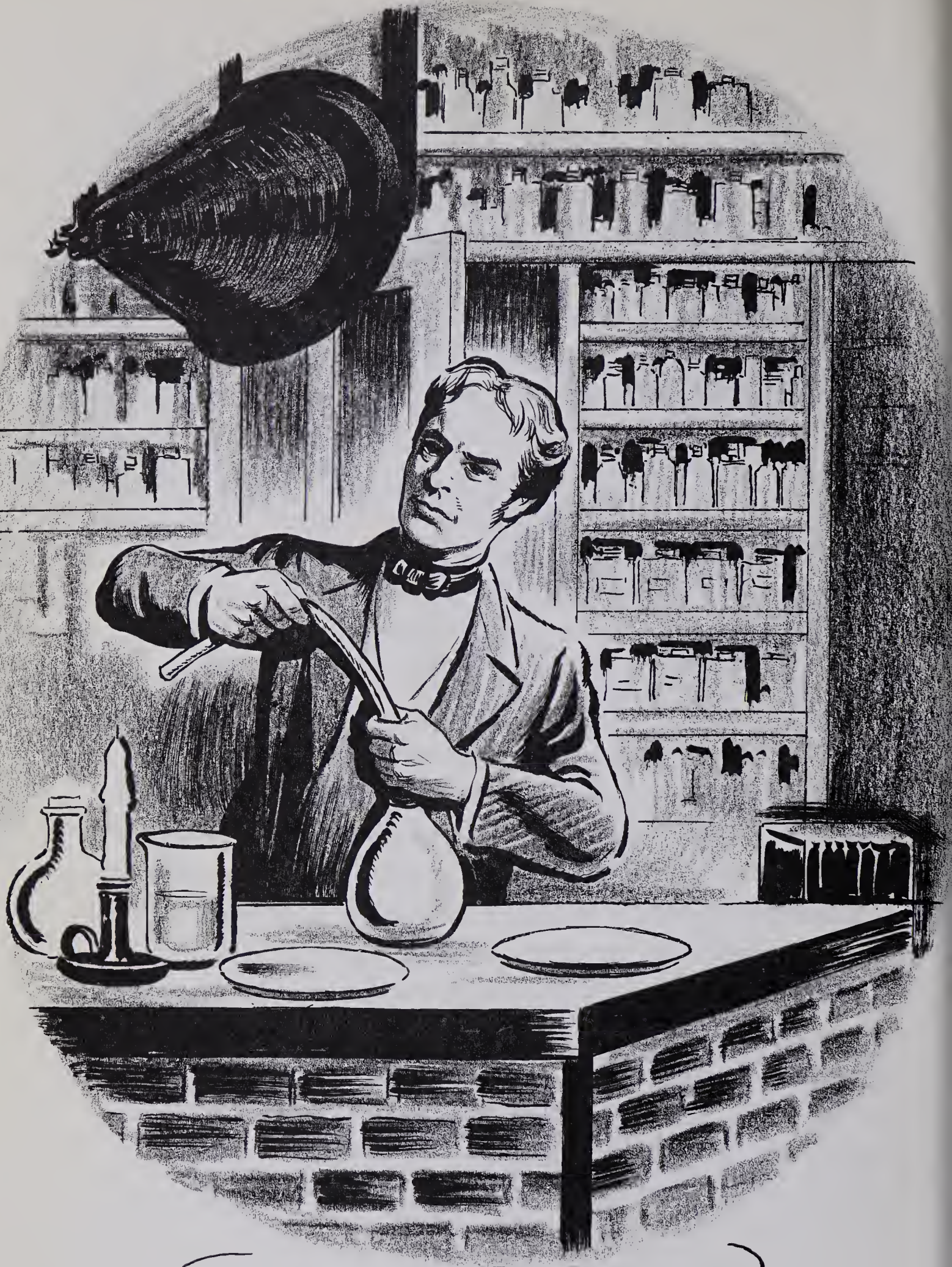
The vulcanizing process not only molds the tread and shapes the tire, but it changes the rubber com-

pound into a durable, elastic material, able to withstand the toughest road conditions.

Before World War I, car owners were happy to get 5,000 miles of wear from a tire. By 1940 the number of miles of wear had increased to 20,500. Today's car owner may expect to get about 34,000 miles of smooth riding, thanks to better and tougher materials in use.

The average passenger tire contains two pounds of natural rubber to eleven pounds of general-purpose synthetic rubber. The largest truck tires are nearly always all natural rubber, because less heat is built up through friction in natural rubber than in synthetic. There is, however, a synthetic rubber called "polyisoprene" which is now being used in some large tires.

At the present time, the proportion of natural rubber used in this country for all purposes is about one third, as opposed to two thirds of synthetic rubber. In 1958 over 1,200 million pounds of crude rubber were imported into the United States. In 1960 each man, woman and child will be using about 24 pounds of rubber, both natural and synthetic, a staggering total of over 4,200,000 pounds. In 200-pound bales piled on top of one another, this would make a stack more than 2,800 times the height of the Empire State Building.



E. Faraday

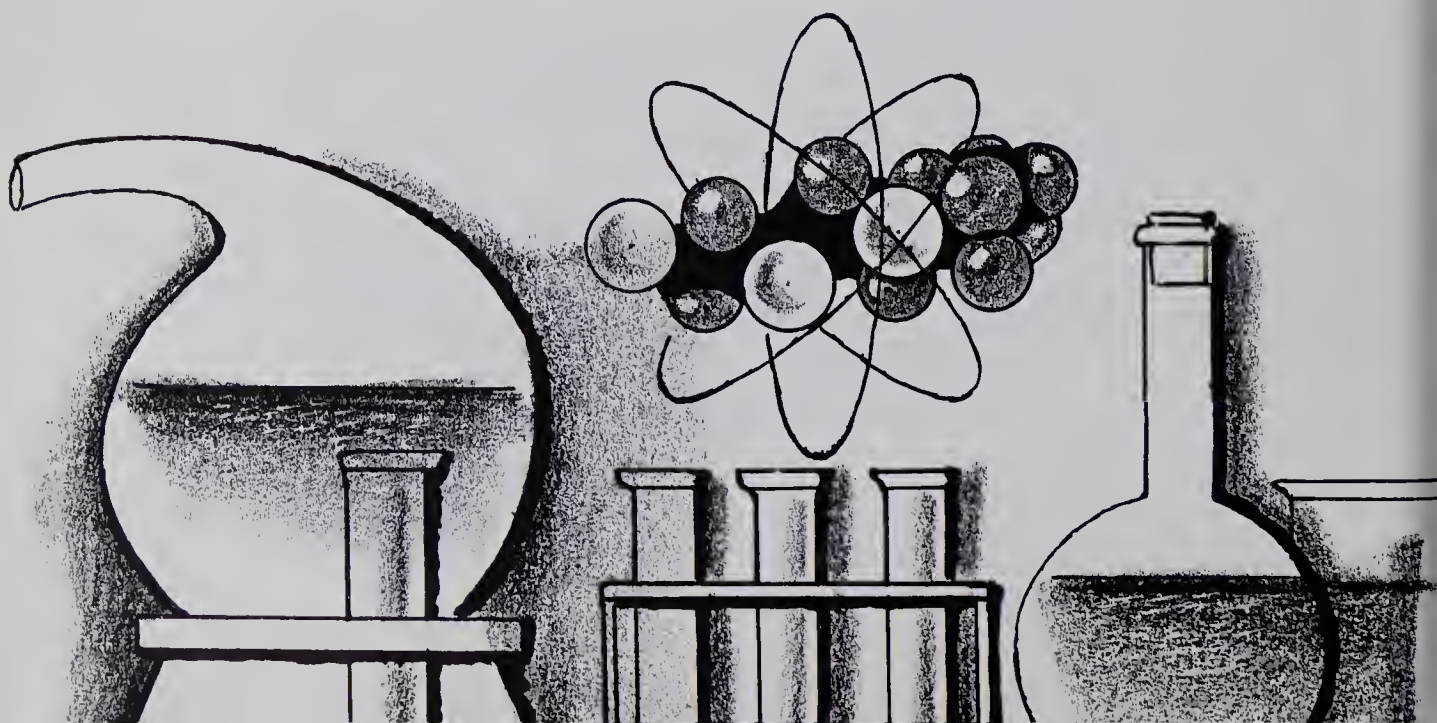
6. Out of a Test Tube

IN THE last chapters the progress of natural rubber was followed from the time it dripped out of the “trees that weep,” until it rolled off the assembly line in a rubber factory as a brand-new tire to be used on a car someone will buy next month. The history of synthetic rubber is not nearly as ancient as natural rubber’s. The year 1962 will be the 100th anniversary of the discovery that the chemical composition of rubber could be duplicated in the laboratory.

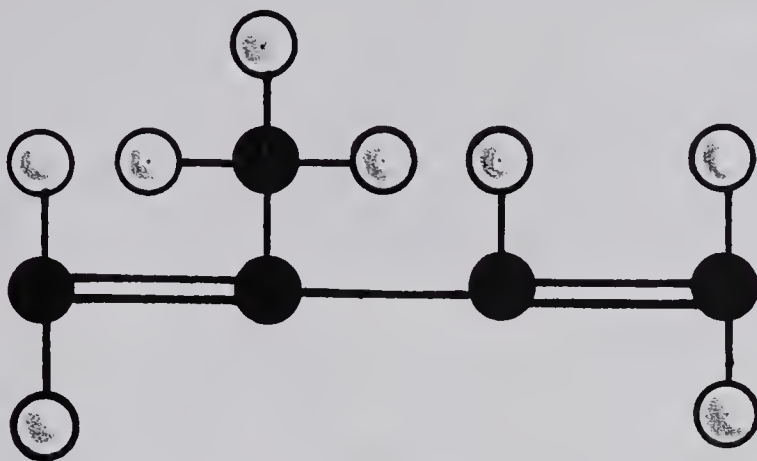
The problem scientists faced was to find out just what gave rubber its unique qualities of springiness and bounce. Michael Faraday, an Englishman, found in 1862 that rubber was made up of five atoms of carbon and eight atoms of hydrogen. Its chemical formula is a multiple of C_5H_8 , written as $(C_5H_8)_N$. This particular arrangement of carbon and hydrogen atoms is called a “rubber molecule.”

Any material composed of hydrogen and carbon is known as "hydrocarbon." There are a great many hydrocarbons besides rubber. Some of the commonest are natural gas, gasoline, turpentine, coal, and kerosene. These other hydrocarbons are different from rubber because, for one thing, the arrangement of the carbon and hydrogen atoms is different. There is more carbon in coal, for instance, and more hydrogen in gasoline.

Another Englishman, Granville Williams, in the same year that Faraday's discovery was made, managed to isolate the molecules of rubber, which he called "isoprene." Williams found that the atoms in the molecules were distributed in a peculiar manner. Four of the carbon atoms were arranged in a chain, with five hydrogen atoms branching off. From one of the carbons in the chain another carbon branched off, surrounded by three hydrogens. Atoms will always be found in this arrangement in the molecule of natural rubber.



If you have a group of black jelly beans, corresponding to the carbon atoms, and a group of white jelly beans, corresponding to the hydrogen atoms, you can arrange them with some matchsticks, to form this pattern:



Rubber is composed of a great many of these molecules, hundreds of thousands of them, linked in long chains to form giant molecules, called “polymers,” from the Greek *polymeres*, meaning “many parts.” The process of linking these smaller molecules into a bigger chain is called “polymerization.”

It is believed that rubber stretches because of its chainlike molecular make-up. The long chains of rubber molecules link and twist like springs. When the rubber is pulled the spring stretches out, and when released the spring flies back again. No other natural substance has this peculiar arrangement, and that is why rubber tires will stretch when inflated with air and why a rubber ball will bounce.

It seemed an easy matter for scientists to duplicate rubber in the laboratory, since it is composed of only two common elements, carbon and hydrogen. But the special chainlike arrangement of the molecules proved to be the stumbling block. Failing to duplicate natural rubber, chemists began to experiment with other materials in the hydrocarbon family to arrive at a substitute.

Early experiments did produce a number of rubber alternatives but nothing as good and as cheap as the natural product.

In World War I, when Germany was cut off from natural rubber supplies, their scientists began in earnest to solve the difficult problem of making synthetic rubber. They finally developed a rubber substitute, and by 1918 were producing 50 tons of this product a month.

There is an old saying, "An army marches on its stomach." This may have been true in Napoleon's time, but today's army marches, or rather rides, on rubber. Modern warfare is mechanized warfare. Jeeps, tanks with rubber treads, and other military vehicles carry troops and equipment over rough ground at high speed. Cargo planes drop men and supplies at strategic points. In all this, rubber plays a most important part.

Even in World War I rubber was beginning to assume a major role. When the Germans were only twenty miles from Paris, in September of 1914, more French



troops were called for in a hurry. Every type of vehicle, including buses, trucks, private automobiles, and taxis, were loaded with soldiers. Over shell-torn roads bounced this taxicab army, arriving at the front in time to stop the German advance. Paris was saved, and rubber paved the way to ultimate victory.

When the war was over, experiments on synthetic rubber still continued, but on a reduced scale. Natural rubber was so much better and cheaper that there seemed to be no good reason to develop it in the laboratory.

This picture changed quickly with the beginning of World War II. Once again Germany was cut off from natural rubber supplies. This time her scientists came up with man-made artificial rubber, called "Buna S" and "Buna N," which made Germany independent of natural rubber.

As early as 1940 the United States Government had asked the rubber industry to build four synthetic rubber plants. With a war raging in Europe, it became apparent that a substitute for natural rubber might have to be found.

When the Japanese overran the Malay Peninsula, this quickly became true. Within three months, 95 per cent of the world's natural rubber was in enemy hands. The loss of this Far East rubber was a great blow to the Allied nations. A substitute had to be found and had to be found fast.

After Pearl Harbor, the best skill and talent were immediately put to work on the task of finding a rubber substitute. More plants were built, and scientists began their experiments with the synthetic German Buna rubber. With the addition of styrene and other ingredi-

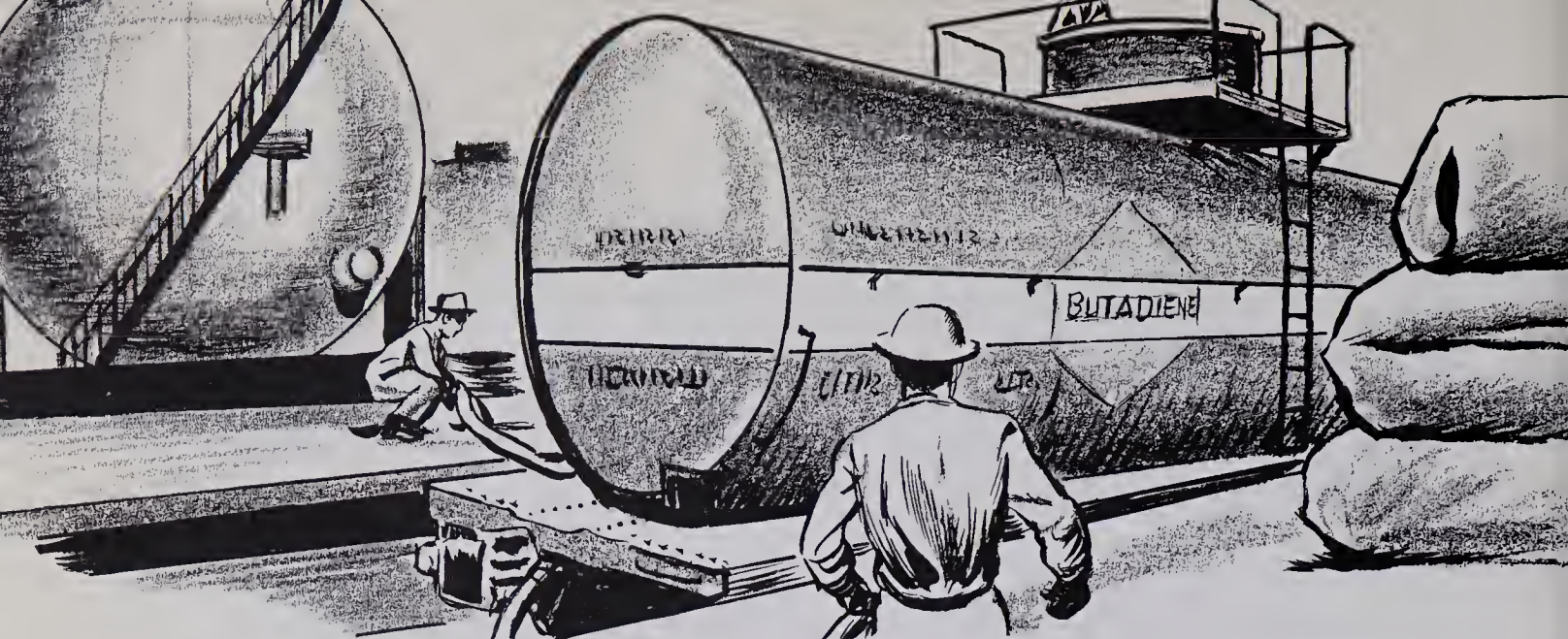
ents, a new type of synthetic rubber appeared called “GR-S,” or “Government Rubber Styrene.” That was its wartime name. This same kind of synthetic rubber is now called “SBR,” the initials of Styrene-Butadiene Rubber.

So quickly did this new product get into development that between Pearl Harbor and August 1945, the United States made as much synthetic rubber as the entire world output of natural rubber between 1900 and 1916. In 1941, 8,000 tons of synthetic rubber were made. This figure soared to 820,350 tons by 1945.

The manufacture of synthetic rubber is a complicated process, but briefly here is what happens.

You will remember that rubber is a hydrocarbon: a material composed of hydrogen and carbon. Scientists found two other hydrocarbons that were ideally suited to the manufacture of synthetic rubber. One is called “butadiene,” and is obtained from petroleum, alcohol, or coal. Butadiene is a gas, but under pressure it turns into a liquid. If allowed to stand long enough it polymerizes. The small butadiene molecules link together into big molecules of synthetic rubber. This rubber is of poor quality, so styrene is added to give it more durability and bounce. Styrene, also a hydrocarbon, is a liquid like gasoline, and is made from coal or petroleum.

Every day freight locomotives push a long line of



tank cars containing butadiene or styrene into modern factories. These two products are piped into storage tanks at the factory until ready for use.

Inside the synthetic rubber plant there is a jungle of dials, catwalks, and pipes. Through a small glass window, chemists watch butadiene and styrene swirling about in the mixing tank, along with soapy water which has been added to help the rubber molecules to form. This mixture is whipped until the butadiene and styrene form droplets in water and polymerization begins. A chemical catalyst is added to the mixture to speed up the action. This swirling liquid becomes a synthetic rubber latex, very similar to the natural rubber latex from the rubber trees.

In a central control room a chemist mixes the ingredients which go into the tanks by turning knobs and dials, and measuring amounts and temperatures as he follows the special recipe for this batch of synthetic rubber. The recipe may vary considerably, since there are 500 varieties of all-purpose GR-S synthetic rubber alone.

From the mixing tank, called a “polymerizer,” the liquid latex goes into large wooden tanks called “coagulators.” These tanks contain salt brine and acid. As the mixture coagulates, or solidifies, it forms into crumbs and begins to look like light brown popcorn.

This popcorn, after being filtered and washed, is carried by a conveyer belt to the drying room, where the water is removed by warm air. In a press the dried rubber is formed into 75-pound bales.



Perhaps the most important thing about synthetic rubber is that in some ways it is superior to natural rubber. Both its quantity and quality are more easily controlled than plantation rubber's. It is also more simply and economically processed.

Some of the synthetic rubbers are oil and heat resistant. They play an important part in the construction of automobiles and airplanes. The petroleum industry is making use of special types of oil-resistant synthetics in pump seals, transmission belts, and all kinds of molded parts.

In service stations, hoses are used that are resistant to gasoline. The attendant may even wear special shoes that are not affected by oil or grease. Chemical workers use rubber gloves that are impervious to alkalis, acids, and solvents. Rubberized fabric tanks for the temporary storage of fuels are now being used by some companies. They can be easily transported, cleaned and stored.

Natural rubber will always be indispensable for many of the articles everyone takes for granted, but in making synthetic rubber such a versatile product, the scientists have managed to improve on nature. There is plenty of room in this busy, complex world for both kinds of rubber, and there is no doubt at all that both will become even more useful in the future.

7. Silk Purses and Sows' Ears

ONLY the scientists in the laboratories of vast rubber companies all over the world can tell us just what new miracles can be expected of rubber in the future. The old saying goes, "You can't make a silk purse out of a sow's ear," but recent developments in rubber research have proved that there is almost nothing that cannot be made from rubber.

In recent years, the rubber industry has invaded the world of plastics. "Plastic" means anything that is capable of being molded or formed. In that sense, then, rubber is the original plastic. As we have come to know the word "plastic," however, it means any of a great variety of synthetic materials which are being used to replace wood, glass, wool, silk, and even rubber itself.

"ABS" is the nickname which scientists have given to a remarkable product which is a mixture of plastic

and synthetic rubber. It needs a nickname, because its full name is Acrylonitrile-Butadiene-Styrene, which is quite a mouthful. ABS is very hard and tough, and anti-corrosive. This means that salt, acids, and other chemicals cannot harm it.

For this reason, it is particularly useful in making all kinds of piping. All in all, there are almost 10,000 miles of ABS piping in the United States today, and that figure is growing all the time. Golf courses use it for underground sprinkler systems, tanneries and other factories use it for carrying strong chemicals and acids. Tanneries used to use galvanized iron piping, but it corroded so quickly that it needed to be replaced every few weeks. ABS may soon make this inconvenience a thing of the past. Along with the precious oil in an oil field comes a great deal of useless salt water; ABS pipes channel this away. Many farms in the West use natural gas as a fuel to power their irrigation systems. ABS pipes are now bringing it to them from the huge main trunk lines. These are only a few uses for this light, practical new piping.

One of the dramatic qualities of ABS is what the scientists call its "memory." There are boat hulls, for instance, now made of this product. If your father were to dent his fishing boat when he was mooring it, he could repair it very simply, just by borrowing your mother's electric hair drier. He would heat the dented

part by blowing hot air on it, and the hull would snap back into its original shape. One of these days, car bodies may be made from ABS, and wives will no longer be afraid to confess to their husbands that they have dented a fender.

Have you ever looked behind the instrument panel in an automobile when the oil gauge or speedometer was being repaired? Do you remember the complicated maze of wires you saw, twisting and winding every which way, so that it was difficult to tell them apart, and even more difficult to know which one needed to be fixed? Well, there is a new kind of instrument panel, made of ABS, which has the wires for all the various gauges built right into it. The wires are coiled neatly around the back of the panel, flattened out and glued securely. Whenever a car owner has wire trouble, all he has to do is lift out the entire panel and insert a new one. They are light in weight and very cheap, and the rubber in their composition provides excellent insulation.

Many other things are now being made from this new product of rubber research. Refrigerated truck liners, fishing rod handles and reels, all kinds of toys, football helmets, camera and typewriter cases, portable radios. The list goes on and on.

Rubber has undergone other transformations which have produced whole new classes of rubber products.

To create an entirely different material from rubber, engineers and scientists have borrowed an idea or two from the bakery.

When a baker makes a meringue topping for a lemon pie, he beats egg whites in a bowl and adds a dash of sugar and vanilla. The result is a pure white, frothy mass, piled high over the edges of the bowl, with thousands of tiny air bubbles.

Making foam rubber is very much like making meringue. For years, scientists worked to perfect a good solid rubber. Then they turned around and began filling it full of holes.



Before 1949, liquid latex was beaten into a froth in a machine that looked something like a giant egg beater. The latex was mixed with air in just the same way



that a baker makes meringue. That is why it is so soft and light and so pleasant to sleep, sit or walk on. This air-filled latex was then molded and baked, just like the meringue in the kitchen. In a new, modern technique, the latex is beaten in a high-speed beater called

an “aerator.” It flows in a continuous stream from this machine into molds.

The world is a softer, more comfortable place to live in since the invention of foam rubber. Its light weight, buoyancy, and cleanliness make it a very important product in the manufacture of mattresses, pillows and furniture. It is an ideal cushioning on trains, buses and boats.

Still another example of the amazing transformation synthetic rubber has undergone is its mixture with various chemicals to produce hard rubber. It is difficult to remember that this substance is, after all, rubber. No one would dream of trying to bounce a bowling ball! Other things made from hard rubber are combs, pens, tool and knife handles, photographic developing equipment, mouthpieces for musical instruments and many other items.

If you stop to think about it, it seems incredible that two such different objects as a bowling ball, which some people can hardly lift, and a foam rubber cushion could both be made from just one substance. But they are. Perhaps the sage was wrong, and silk purses *can* be made from sows' ears.

8. No End in Sight

NATURE is not entirely predictable, and it is possible that the day will come when the rubber industry can no longer count on all the natural rubber it needs. That day is a long way off, but the research staffs of the rubber companies will be ready for it when and if it comes. Their experiments in new uses for synthetic rubber and other new types of this material are going on all the time. Rubber has already replaced wood and metal to a considerable extent and industries of all kinds will certainly depend on it more and more in the future.

The United States Government alone, for instance, is an enormous consumer of all types of rubber products, some of which used to be made from other materials.

There are tires and other rubber parts for airplanes,

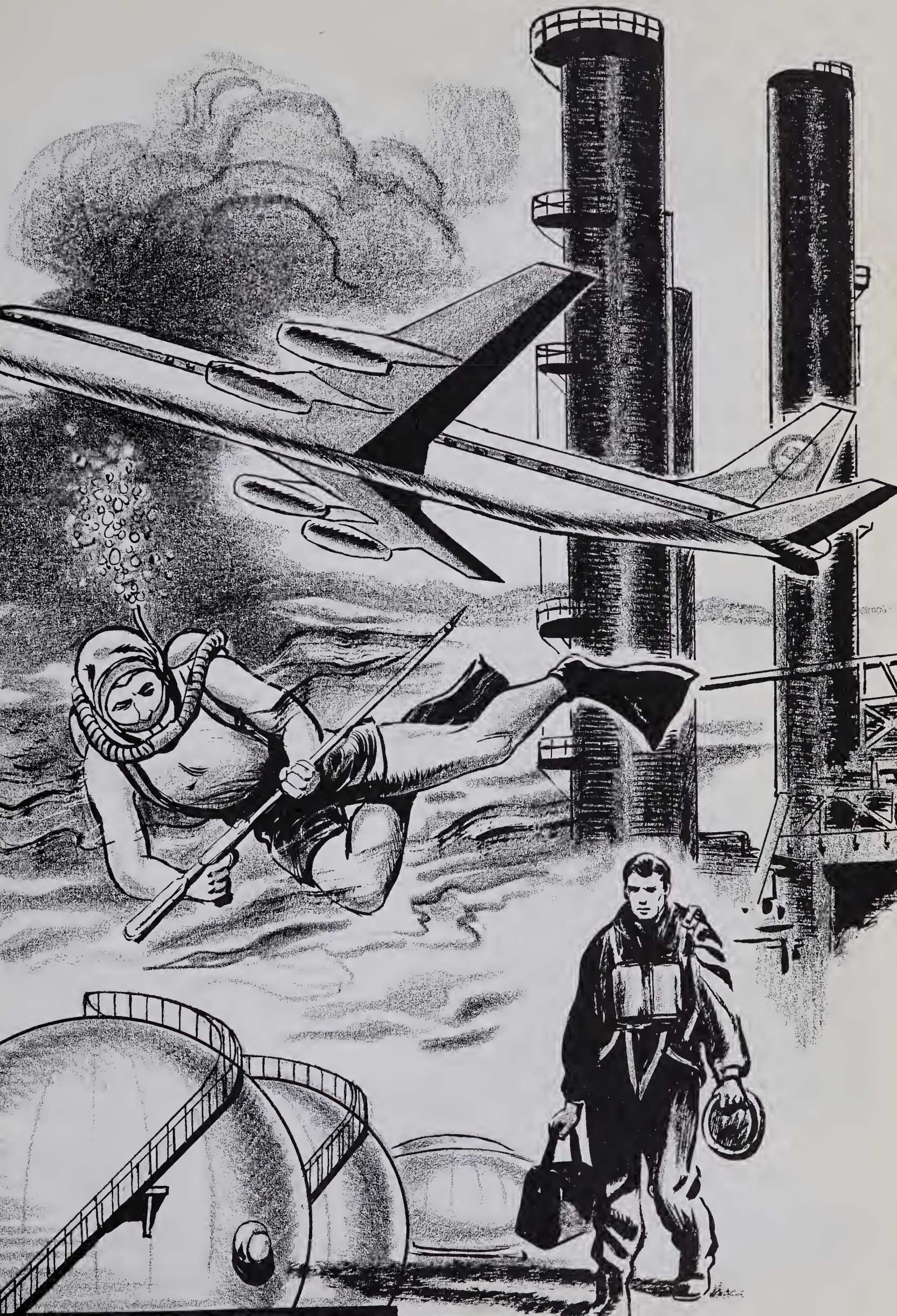




tanks, tractors, and jeeps. Containers have been developed that can be dropped without damage from airplanes at great heights; they may bounce after falling 50,000 feet, but they don't spread out all over the landscape. Special fuel tanks like giant doughnuts roll over rough terrain without wheels. When an airman pulls the rip cord, after bailing out, there is a great jolt and jar as the parachute opens, and his free fall is abruptly slowed down. A rubberized parachute harness takes up much of this shock.

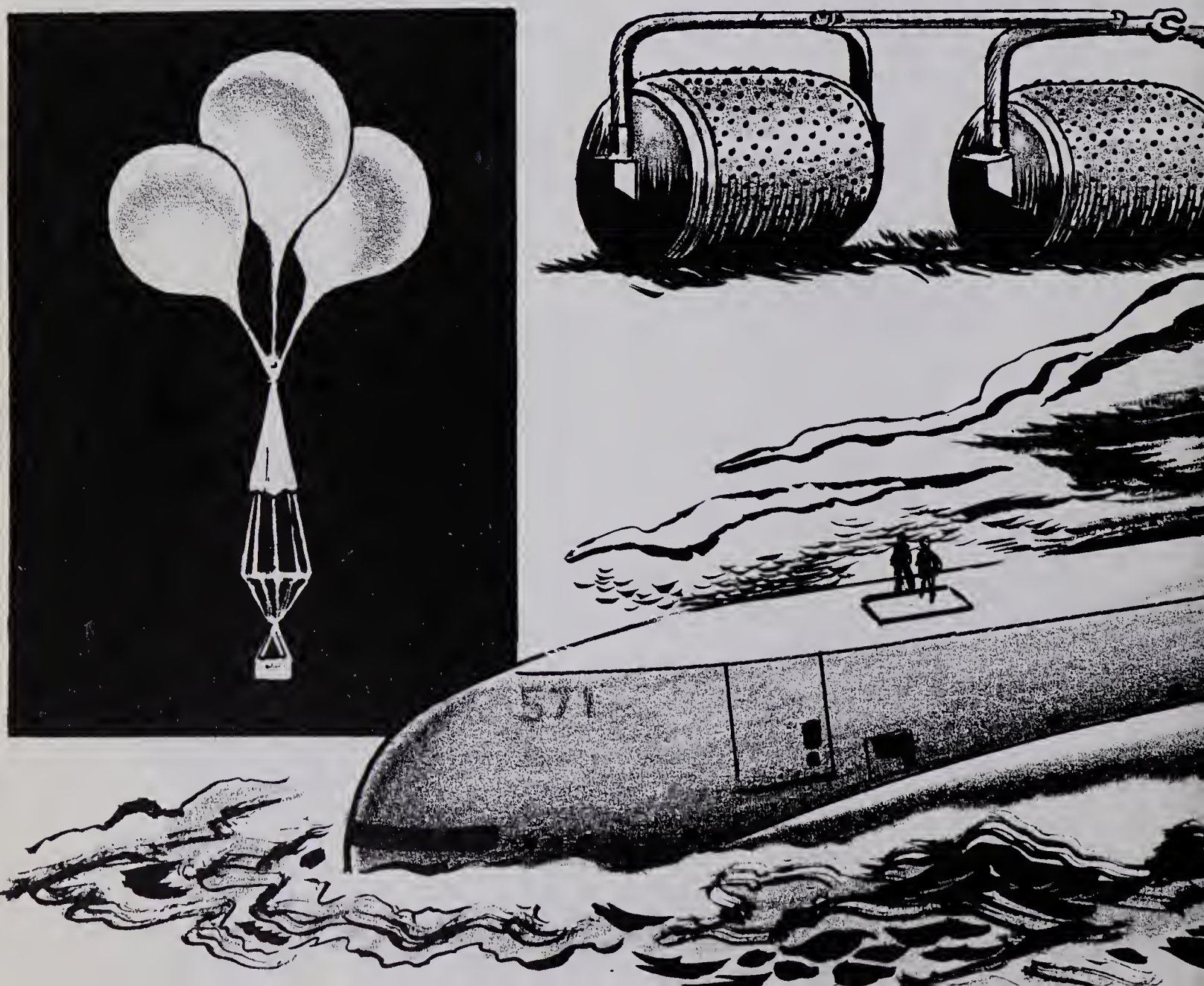
The underwater frogman wears a special rubber suit and insulated plastic underwear. He uses rubber gloves for working on delicate mechanisms beneath the sea. Escape hatches from submarines are insulated with a rubber lining, and rubber expansion joints keep the vessel silent so it cannot be detected by the enemy. A rubber timing belt in the atomic submarine *Nautilus* keeps its power drive silent, to prevent any vibration from being picked up by the electronic ears of an unfriendly power. These timing belts are also used in military machines. Ship engines, too, are cradled in rubber to cut down vibration. The sailor who sits on a sling overside, painting the bow of his ship, dips his brush in a special rubber paint that prevents corrosion.

The new jet planes have self-sealing fuel tanks, made from rubberized fabric, in their thin wings. Rubber is also used in headgear for fliers, oxygen masks, light-



weight flying suits, footwear, life boats and life jackets.

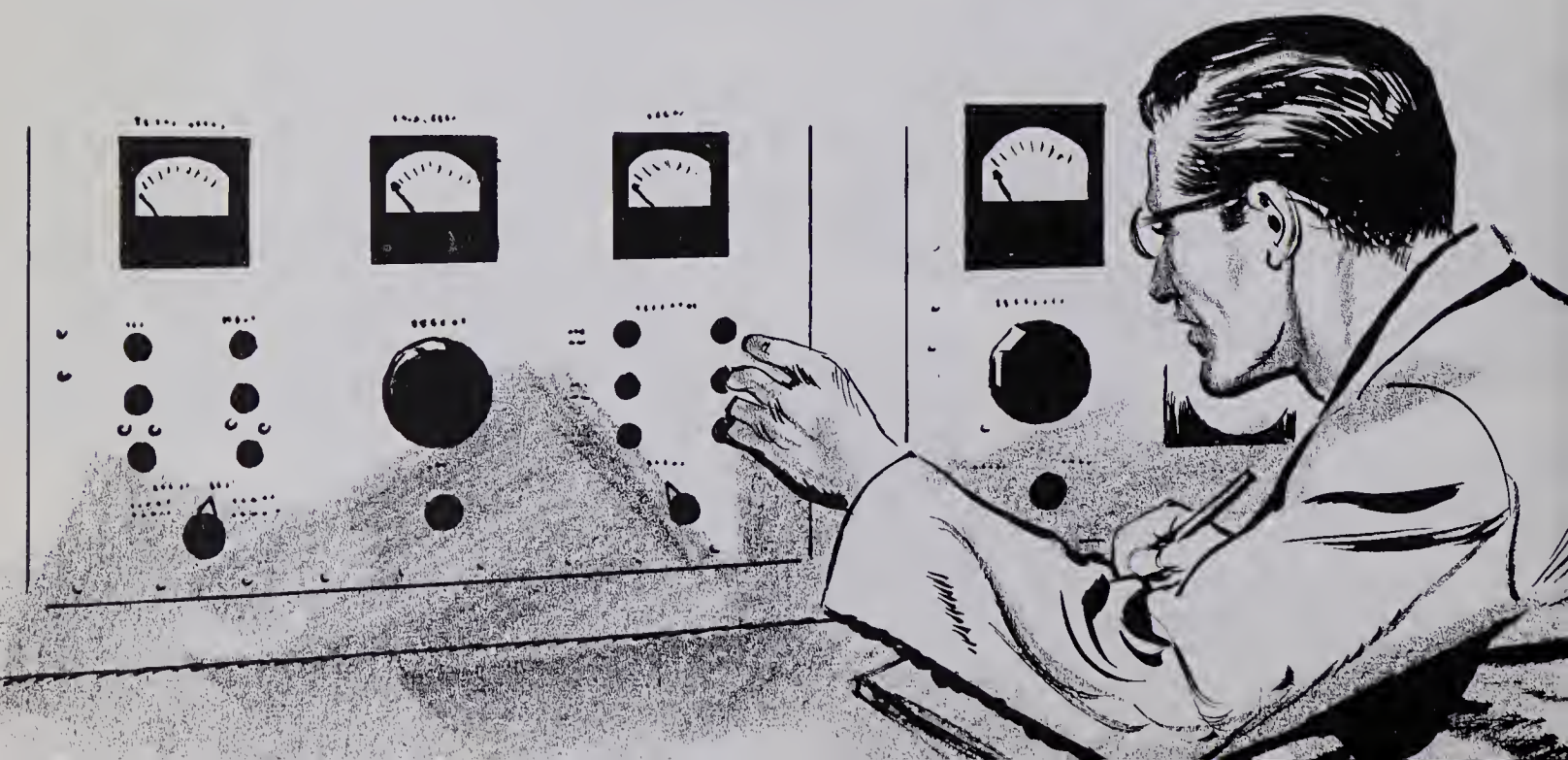
All of these things are in the present. Rubber in the future is another story. "Research in rubber today is helping to crack tomorrow's barriers of time and space," says a scientist in one of the big laboratories of a rubber company. Behind the glass walls of this research center chemists are engaged in the never-ending search for new uses and new combinations. Now they have a modern tool to help them: atomic energy.

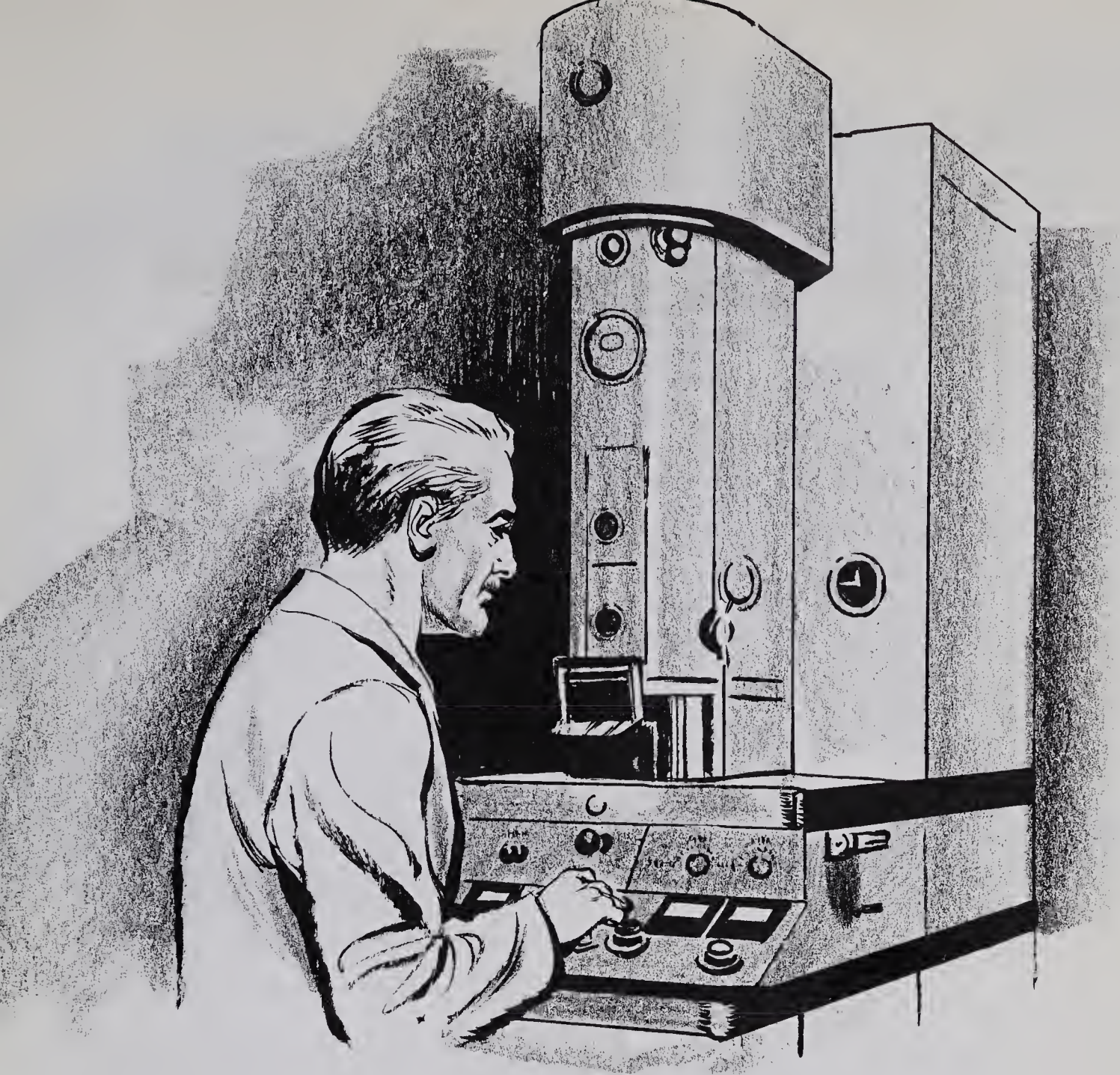




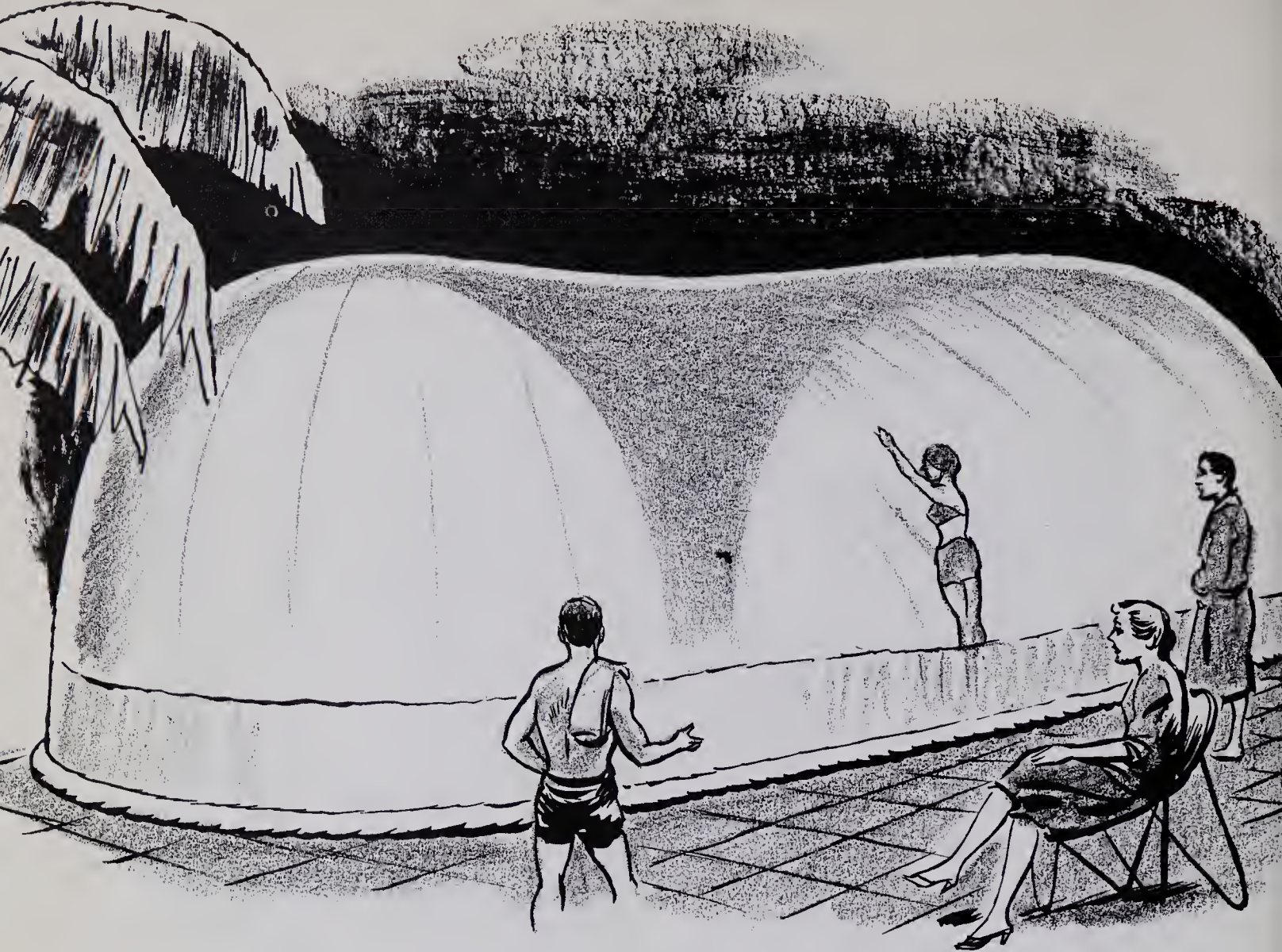
Radioisotopes are used to check the quality of rubber, and also to control the thickness of plastic coatings. An atomic device, the beta ray gauge, checks the dimension of rubber-coated tire cord and signals if the coating is not of the required thickness. In place of the old method of vulcanizing, some rubber products are now cured by radiation.

In one laboratory, a conveyer belt brings samples of rubber into a chamber protected by walls of thick concrete. In front of an electron accelerator sits a scientist at an instrument panel. The scientist watches the progress on the instrument panel as the rubber samples are bombarded by millions of electron volts. These volts are breaking down the original molecular structure of the rubber. In this way, the scientist is trying to form other patterns of hydrogen and carbon atoms which may give rubber still new and previously unknown properties.





How will all our lives be different in the future as a result of rubber research? For one thing, mothers may not have to buy whole new wardrobes for their children as they outgrow all their clothes. When a boy is two, his mother can buy him a shirt made of a special rubber which will grow right along with him, so that he is still wearing it when he is six or seven. There will probably be dresses made of the same material that will fit girls and women alike, and bathing suits that can be carried in a purse.



Can you imagine a building made of rubber that is “built” by being inflated like a balloon? Some already exist, and more will, undoubtedly, in the future. One of them was designed by Frank Lloyd Wright, the famous architect, several years ago. They can be used as warehouses, circus tents, movie theatres, etc. Films were shown in one of these rubber buildings at the Brussels World Fair in 1958. Even though their walls are flexible, they are very sturdy, since their bases are securely anchored by a thick rim filled with sand or water.

Similar rubber structures, much flattened out, may one day be used as secret mid-ocean rendezvous where ships can refuel and make minor repairs. Looking like a huge beret, they are inconspicuous and cannot be detected by radar.

All of these things are in extremely limited use today. Some of them are still in the planning stage. The future of rubber is unlimited. Chemistry and research are creating more miracle products every day. Our standard of living has never been higher, and rubber is one of the things that will make it higher still tomorrow.

We have certainly come a long way from the rubber raincoats that had to be buried because they smelled so bad in July, and that cut the back of a man's neck because they were so stiff in December.

Glossary

Acrylonitrile-Butadiene-Styrene (ABS) — A hard, tough synthetic product which is a mixture of plastic and rubber.

Automation — The process by which the manufacture of any object is done entirely by machine, men having little function other than to watch over the machines.

Bag-O-Matic — A steam-heated mold shaped very much like a watchcase, in which the nearly completed tire is shaped and vulcanized by simultaneous pressure and heat. This type of machine is also called an Autoform.

Calender — A machine in a tire factory which has revolving cylinders between which nylon or rayon tire cord and rubber are joined to form a rubberized fabric, which is the main part of the tire.

Cambium — The soft layer of tissue between the bark and wood of a tree, which contains the cells for the growth of new wood and bark.

Centrifuge — A machine which uses the principle of centrifugal force. By whirling liquid latex in a revolving cylinder at tremendous speed, the water in it, which is heavier than the rubber, is forced out of the mixture.

Coagulum — The name for natural rubber in its spongy curdlike form just before it is smoked or air-dried.

Hevea brasiliensis — The botanical name for the most widely cultivated rubber trees.

Hydrocarbon — Any substance, such as rubber, coal, gasoline, the molecule of which contains atoms of carbon and hydrogen.

Latex — Rubber in the milky liquid form in which it is taken from rubber trees.

“Merry-go-round” — A revolving platform in the largest tire manufacturing companies, on which all the machines for making a tire are fastened and perform completely automatically.

Molecule of rubber — The smallest quantity of rubber, containing five atoms of carbon and eight atoms of hydrogen in the unique arrangement which gives rubber its particular qualities.

“Pickle” — A machine invented by Thomas Hancock, which used a revolving spike to re-form bits and scraps of rubber into a solid mass.

“Pie cutter” — One of the machines in a tire factory, in which heated blades cut up large bales of crude rubber into small pieces.

Ply — One of the layers of rubberized fabric which make up the main part of a tire. Tires are usually either four- or six-ply.

Vulcanization — The process whereby rubber is strengthened and stabilized by the addition of sulphur and the application of heat.

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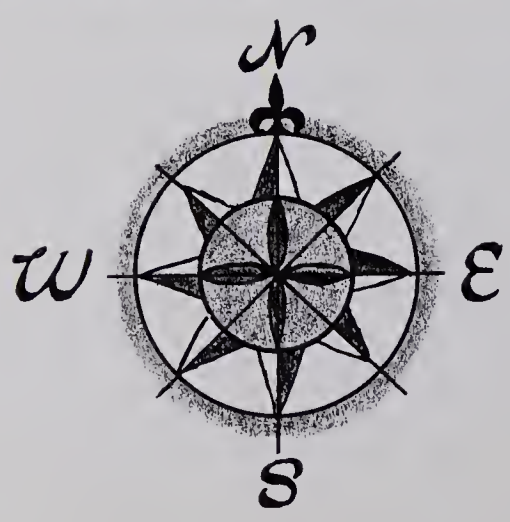
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